International Journal of Management, Economics and Social Sciences
Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017)
2018, Vol. 7(S1), pp.1 – 12.
ISSN 2304 – 1366
http://www.ijmess.com

An Analysis of the Medical Expenses of a Bronchia and Pulmonary Cancer Group by Two-Stage Cluster Method

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The objective of this study is to discover the influencing factors of groups by gender and age and the expenses related to bronchial and pulmonary cancer for insight into the root of the problem. An aging population has generated huge expenditures in cancer care. This study proposed a two-stage cluster method by using k-means and a Self-Organizing Map (SOM) to conduct a scientific analysis of the health insurance database of cancer prescription and patients in 2016. The findings of this study revealed that bronchial and pulmonary cancers were responsible for the largest medical expenditure; the average cost was $306,776 for females aged 50 to 54 and $301,788 for males aged 65 to 69. Meanwhile, the results indicated that incidences of bronchial and pulmonary cancer were concentrated in the ages between 45 and 89 for both males and females, with such incidences representing enormous cancer care expenditure. The implications are summarized in this article.

Keywords: Two-stage cluster method, tumors, cancers, data mining, self-organization map, k-means

The occurrence of malignant tumors remains one of the greatest threats to human health and life. With the change in global social patterns, the progress of science and technology, and the change in living habits, the incidence rate of such tumors has risen gradually, leading to the rise in demand for medical treatment resources. The leading causes of death have changed drastically along with the economic boom and advancements in public health in Taiwan since the early 1950s. Malignant neoplasm has been the leading cause of death in Taiwan since 1982 (Chen, You, Lin, Hsu, & Yang, 2002). According to statistics released by the Ministry of Health and Welfare of the Executive Yuan, the major causes of death and the top ten causes of death in Taiwan in 2015 were: (i) malignancy, (ii) heart disease (except hypertensive disease), (iii)

Manuscript received May 20, 2017; revised August 28, 2017; accepted October 5, 2017.
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cerebrovascular disease, (iv) diabetes, (v) pneumonia, (vi) accidental injury, (vii) chronic lower respiratory disease, (viii) chronic liver disease and cirrhosis, (ix) hypertensive disease, and (x) nephritis, nephropathy and nephropathy, where the death toll from malignancies was 42,559 (i.e., 183.5 deaths per 100,000 population at a mortality rate of 28.03%) (Chiang, Yang, You, Lai, & Chen, 2013), as shown in Table 1. The top 10 major cancer deaths in the country in 2011 were ranked in the following order: (i) trachea, bronchus and pulmonary cancer, (ii) liver and intrahepatic cholangiocarcinoma, (iii) colon, rectum and anal cancer, (iv) female breast cancer, (v) oral cancer, (vi) gastric cancer, (vii) prostate cancer, (viii) pancreatic cancer, (ix) esophageal cancer, and (x) cervix and some unclear parts of the uterine cancer.

Rank	Tumors	Death Toll	Mortality Per 100,000 Population	Death%
1	**Trachea, bronchus, and pulmonary cancer**	**8,541**	**36.8**	**20.1**
2	Liver and intrahepatic cholangiocarcinoma	8,022	34.6	18.8
3	Colon, rectum and anal cancer	4,921	21.2	11.6
4	Female breast cancer	1,852	16.0	4.4
5	Oral Cancer	2,463	10.6	5.8
6	Gastric cancer	2,288	9.9	5.4
7	Prostate (prostate) cancer	1,096	9.4	2.6
8	Pancreatic cancer	1,607	6.9	3.8
9	Esophageal cancer	1,507	6.5	3.5
10	Cervix and unclear parts of uterus cancers	681	5.9	1.6
11	Other	9,581	41.3	22.5

Table 1. Ten Major Causes of Cancer Death in Taiwan in 2016

As Table 1 shows, tumors of the trachea, bronchus and pulmonary account for the highest percentage of health care costs in cancer therapy. At present, whether the cost of medical care generated by cancer relates to the age and sex of patients has been lacking. The likely reason for this gap in the literature is the difficulty of collecting large amounts of treatment data and medical information to conduct scientific analysis and estimation, such as data from the National Health Insurance Database (NHID). More than a hundred articles based on the health care costs of individual hospitals have been published in various fields since 1975 (Hay & Mandes, 1984; Vogel, 1984). However, these studies focused on the health care costs of the emergency special illness and service quality (Meyers, Madhwani, Rausch, Candrilli, Krishnarajah, & Yan, 2017; Ruiz, Charpak, Castillo, Bernal, Ríos, Trujillo, & Córdoba, 2017; Seiffert, Schneider, Roessler, Larisch,

& Pfeiffer, 2017). They did not analyze care costs for tumor patients of trachea, bronchus and pulmonary cancers.

To remedy the gaps in previous studies, this study will propose a model by using two-stage clustering method, the Self-Organizing Map (SOM) and k-means algorithm, and collect the data of the Taiwan Health Care Costs for Cancer Patients to explore the classification groups of bronchial and pulmonary malignancies and medical costs. The research processes and purpose of the study were as follows:

1. Using a two-stage clustering method together with techniques of SOM and k-means algorithm technologies;
2. Conducting a scientific analysis on a large amount of cancer treatment data obtained from health care databases, and using SOM to group the medical expenses of cancer patients; and
3. Applying the k-means algorithm to find the best group in order to discover the relationship between tumor patients' property data and medical costs.

LITERATURE REVIEW

-Tumor Definition

When one of the cells in the human body becomes abnormal due to factors that affect surrounding cells, which then produces sarcoma or local mass, it is called a tumor (Peg, Sansano, Vieites, Bernet, Cano, Córdoba, Sancho, Martín, Vilardell, Cazorla, Espinosa-Bravo, Pérez-García, Cortés, Rubio, & Ramón y Cajal, 2017). Cancer is the most common malignant tumor caused by factors resulting in the generation of abnormal cells that causes disease. In addition to monstrous division, cancer cells invade into the normal tissue around them and even transfer to other parts of the body (Sonoshita & Cagan, 2017). Tumors are divided into benign and malignant categories. The malignant category is a new creature of human body tissues formed by abnormal cells, which is more harmful to health. It is characterized by its abnormal growth and special metabolism. Due to rapid growth and poor differentiation, it can not only damage the structure and function of normal tissues, but also transfer to important organs and systems such as brain, pulmonary, and liver, through the blood or lymphatic circulation. It is life-threatening if not treated in time. However, there

are a small number of cancer patients who have survived for a period of time or even self-disappeared without receiving any treatment (Peg *et al.*, 2017). Tumor classification is the key in determining the prognosis of patients as well as determining the type, length and intensity of treatment (Evans-Knowell, LaRue, & Findlay, 2017; Gross & Hanna, 2017). Criteria for tumor classification are as follows:

1. The anatomical location of primary tumor and metastasis, such as pulmonary, breast, or colon.
2. Tissue type and histological classification.
3. Histological grade of malignant extent.
4. The extent of tumor progression, including the size and metastasis extent.

Cancer staging is based on the extent and severity of the original tumor and the extent of its invasion in the body. For the majority of cancers, the stage of cancer can be roughly divided into four phases: Phase 0: changes before tumor invasion; Phase I: limited location of primary tumor in original organ; Phase II: the size and number of tumors invaded by the primary tumor in the original organ; Phase III: tumors invade and spread to neighboring lymph nodes; Phase IV: tumors invade and spread to distant lymph nodes or tissues (Chen *et al.*, 2002).

-Two Stage Clustering Method

This study, mainly using two-stage clustering method and combining with techniques of Self-Organizing Map (SOM) and k-means algorithm, examined a large number of cancer patients obtained from health care databases. The research tools used are as follows. Firstly, SOM is an unsupervised learning neural network proposed by Kohonen in 1973, which can extract the characteristics and relevance of the data itself from the input data (Kohonen, Schroeder, Huang, & Maps, 2001). SOM is mainly used in data clustering analysis, in which a large number of data with similar characteristics can be aggregated by SOM analysis (Seno, Kasai, Ikeda, Vaidyanath, Masuda, Mizutani, Murakami, Ishikawa, & Seno, 2016). It is derived from the framework of competitive neural network architecture, of which the neurons will present a meaningful topological structure in the output space in accordance with the characteristics of input data. Since the generated topological structure can represent the classification of different input data characteristics, it is, therefore,

called the Self Organizing Map Network (SOM). Secondly, the k-means algorithm published by J. B. MacQueen in 1967 is a pre-set type of cluster algorithm that tries to find the best cluster organization in accordance with a pre-set number of clusters (Dubey, Gupta, & Jain, 2016; Pena, Lozano, & Larranaga, 1999). The k-means algorithm is a partitioned cluster algorithm that divides information in the data into K groups, while the analysis process adopts the quality center in the cluster as a cluster center in order to produce a new cluster center point (Fahrudin, Syarif, & Barakbah, 2017).

METHODOLOGY

The range of research data was collected from the database of cancer prescribing patients of the National Health Insurance Bureau in 2016, which was explored by two-stage grouping method-SOM and k-means algorithm to study the relationship between the property data of cancer patients and the medical expenses. The research model proposed in this study is shown in Figure 1. First, this study compacted tumor-related literature and collected information relating to cancer patients and medical costs. Second, a data preprocess of cancer prescription patients as well as groups representing the status quo were conducted, including the following factors: age, sex, medical items and medical expenses in the bronchial and pulmonary cancer group. Trachea, bronchus and pulmonary cancer account for the highest expenses. In addition, patients' age and gender held the potential to influence medical expenses. When using Microsoft Excel for the data preprocess, the patient' s cancer prescription should be analyzed in order to screen out the current status of bronchial and pulmonary malignancy, age and sex, medical expenses, and groups.

The parameters of SOM with two phases were set. In doing so, we adopted Liao and Wen (2011)'s suggestion. In phase 1, the neighborhood was set as 2, the initial eta and cycles were set as 0.3 and 20 times. In phase 2, the neighborhood was set as 1 and the initial eta and cycles were set as 0.1 and 150 times. In addition, the parameter of the k-means method was set according to Liao and Wen (2011)'s suggestion, such that the number of clusters was set as 7, the maximum iterations were set as 20, and the similarity calculation used the euclidean distance method.

Finally, a two-stage grouping method was used to examine the relationship between tumor patient property data and medical expenses by means of SOM and k-means algorithm. According to statistics of

patient data of cancer prescriptions from the database of the National Health Insurance Bureau in 2016, as shown in Table 2, this study found that items of bronchial and pulmonary malignancies accounted for the highest amount, NT 10, 295,542 Dollars. Therefore, this study focused on the analysis of bronchial and pulmonary malignancies to explore the correlation between bronchial and pulmonary malignancies as well as the association between age, sex factor and medical costs.

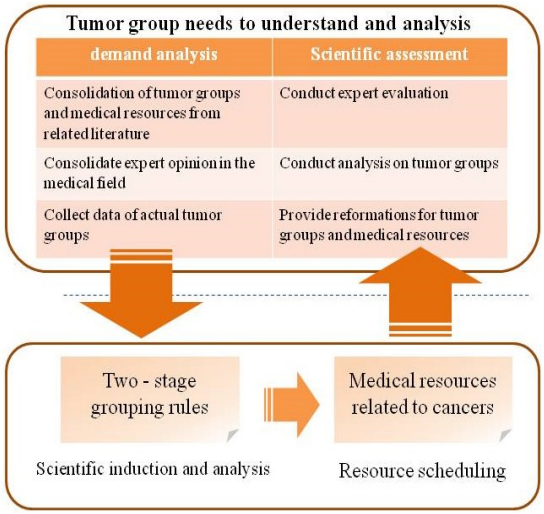

Figure 1. The Research Model Proposed

Cancer prescription category	Amount	Percentage
Bronchial and pulmonary malignancies	$10,295,542	15.2%
Prostate cancer	$9,443,992	13.9%
Nasopharyngeal malignancy	$8,275,769	12.2%
Thyroid malignancy	$8,341,292	12.3%
Primary liver malignancy	$6,359,193	9.4%
Female breast malignancy	$7,897,120	11.6%
Rectal malignancy	$8,045,775	11.9%
Colon malignancy	$4,503,864	6.6%
Gastric malignancy	$2,276,146	3.4%
Bladder malignancy	$2,384,759	3.5%
Total	$67,823,452	100.0%

Table 2. Statistics of Cancer Prescription Category

RESULTS

Based on the data of cancer prescription patient study data from January to December in 2016 collected from the National Health Insurance Administration database and under the data range of bronchial and pulmonary malignancies, this study used SPSS Clementine 10.0 software for clustering and then conducted analysis by using the two-stage clustering of data exploration. In the first stage, the data correlations were

found to serve as a cluster analysis through SOM network and unsupervised learning features. The k-means algorithm was applied in the second stage to determine the best group.

A total of 2,940 cases of bronchial and pulmonary malignancy were collected in this study under the research conditions mentioned in the previous paragraph. A data preprocessing was carried out to avoid inappropriate and erroneous data affecting the results of the survey. Then, a two-dimensional graphic containing the density was produced by SOM network, which was presented in the graphic to understand the differences. The results appeared in seven clusters, which were then served as data basis to analyze factor input by means of k-means algorithm analysis. As shown in Figure 2, it appears in eleven clusters. Then, the detailed medical expenses in each cluster are illustrated in Table 3.

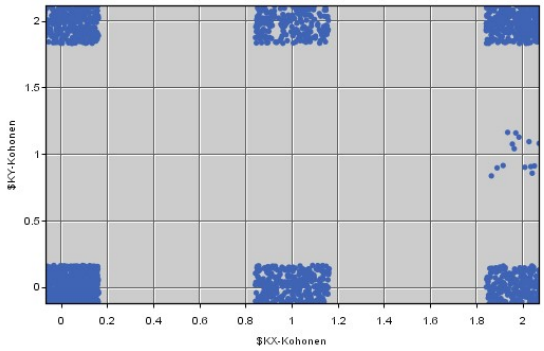

Figure 2. SOM Diagram of Bronchial and Pulmonary Malignancies

On the basis of the data of SOM analysis and the distribution of k-means clusters, the results showed that the ages of bronchial and pulmonary malignancies respectively fall between the intervals of 45 to 89 years of age. In accordance with the age groups defined by the Ministry of Health and Welfare of the Executive Yuan, this study divided the age groups into 0, 1 to 4, 5 to 9, 10 to 14, 15 to 19, 20 to 24, 25 to 29, 30 to 34, 35 to 39, 40 to 44, 45 to 49, 50 to 54, 55 to 59, 60 to 64, 65 to 69, 70 to 74, 75 to 79, 80 to 84, 85 to 89, and 90 years or older.

According to the average cost of medical care in **cluster 1 of males**, the “Average Total Declared Expense” was up to NT279, 233 Dollars along with NT$38,117 Dollars of “Average Surgery Expense” between 50 to 54 years old; the “Average Ward Fee” was up to NT109, 177 Dollars between 55 to 59 years

old; the "Average Cost of Pharmacy Services" was up to NT4,708 Dollars between 60 to 64 years old; the "Average Cost of Drugs" was up to NT72,472 Dollars along with the "Average Anesthesia Fee" of NT18,688 Dollars between ages of 65 to 69; the "Average Special Material Cost" was up to NT47,090 Dollars between ages of 75 to 79.

In accordance with the average cost of medical care in **cluster-2 of females**, the highest cost of "Average Total Declared Expense" was up to NT1,093,606 Dollars along with NT$306,776 Dollars of "Average Cost of Drugs", NT86,617 of "Average Special Material Cost" and NT290,180 Dollars of "Average Ward Fee" between 50 to 54 years old; the "Average Cost of Pharmacy Services" was up to NT10,055 Dollars between 55 to 59 years old; the "Average Anesthesia Fee" was up to NT$59,459 Dollars along with NT91,209 Dollars of "Average Surgery Expense" between ages of 60 to 64.

Based on the average cost of medical care in **cluster-3 of females**, the highest cost of "Average Total Declared Expense" was up to NT70,657 Dollars between 85 to 89 years old; the "Average Surgery Expense" was up to NT27,460 Dollars between 70 to 74 years old; the "Average Anesthesia Fee" was up to NT$11,365 Dollars between ages of 75 to 79; the "Average Cost of Drugs" was up to NT13,595 Dollars between 80 to 84 years old; the "Average Cost of Pharmacy Services" was up to NT3,385 Dollars along with the "Average Ward Fee" was up to NT20,348 Dollars between 85 to 89 years old.

According to the average cost of medical care in **cluster-4 of males**, the maximum cost of "Average Total Declared Expense" was up to NT 707,059 Dollars between aged 65 to 69; the "Average Special Material Cost" was up to NT51,668 Dollars between aged 50 to 54; the "Average Surgery Expense" was up to NT 42,073 Dollars between 60 to 64 years old; the "Average Cost of Pharmacy Services" was up to NT 6,740 Dollars between 65 to 69 years old; the "Average Cost of Drugs" was up to NT 301,788 Dollars between 65 to 69 years old; the "Average Anesthesia Fee" was up to NT 25,799 Dollars between 75 to 79 years old; the "Average Ward Fee" was up to NT 230,394 Dollars between 85 to 89 years old.

Based on the average cost of medical care in **cluster-5 of females**, the maximum cost of "Average Total Declared Expense" was NT101,754 Dollars between 60 to 64 years old; the "Average Cost of Pharmacy Services" was up to NT2,640 Dollars along with NT76,480 Dollars of the "Average Cost of Drugs", NT36,262 of the "Average Special Material Cost", NT23,779 Dollars of the "Average Anesthesia Fee",

NT38,337 Dollars of the "Average Surgery Expense" and NT124,140 Dollars of the "Average Ward Fee" between 65 to 69 years old.

Based on the average cost of medical care in **cluster-6 of males**, the maximum cost of the "Average Total Declared Expense" was up to NT61,068 Dollars between the 65 to 69 years old; the "Average Surgery Expense" was up to NT29,902 Dollars between 55 to 59 years old; the "Average Anesthesia Fee" was up to NT11,382 Dollars between 60 to 64 years old; the "Average Ward Fee" was up to NT18,312 Dollars along with NT2,545 Dollars of the "Average Special Material Cost", and NT1,098 Dollars of the Average Cost of Pharmacy Services between 65 to 69 years old; the "Average Cost of Drugs" was up to NT7,918 Dollars between 70 to 74 years old.

Based on the average cost of medical care in **cluster-7 of males**, the maximum cost of the "Average Total Declared Expense" was up to NT395,265 Dollars along with NT32,948 Dollars of the "Average Cost of Drugs", NT45,808 Dollars of the "Average Special Material Cost", NT59,459 Dollars of the "Average Anesthesia Fee", NT91,209 Dollars of the "Average Surgery Expense" and NT87,420 Dollars of the "Average Ward Fee" between 65 to 69 and 85 to 89 years old; the "Average Cost of Pharmacy Services" was up to NT2,075 Dollars between 70 to 74 years old (see Appendix-I).

To summarize the cluster results above, **cluster 1** revealed that male patients between 55 to 59 years old represented the highest cost in 'Ward Fee' for medical expenses related to bronchia and pulmonary Cancer. The **cluster 2** analysis revealed that the highest cost appeared on 'Drugs' in bronchial and lung cancer in female patients aged 50 to 54 years. The **cluster 3** results indicated that female patients between 70 to 74 years old expend the highest cost in 'Surgery'. The **cluster 4** results indicated that male patients consumed the highest cost in 'Drugs' between 65 to 69 years old. The **cluster 5** results indicated that the highest cost is from 'Ward Fee' for female patients between 65 to 69 years old. The **cluster 6** results revealed that the most cost was consumed in 'Surgery' for male patients aged 55 to 59. The **cluster 7** results revealed that male patients aged 65 to 69 consumed the most cost in 'surgery'. Finally, the study found that the most medical expenses of bronchial and pulmonary malignancies were also concentrated in the middle and high age groups: male patients aged 55 to 59 and 65 to 69, and female patients aged 50 to 54, 65 to 69 and 70 to 74. Meanwhile, elderly patients incur medical expenses in drugs, ward and surgery. This means that these

medical items were required often, resulting in medical expenses being consumed due to the number of elderly people suffering from malignant tumors, which will increase following the proportion of the future increase in the elderly population.

CONCLUSION AND RECOMMENDATIONS

In Taiwan, the higher incidences of tracheal, bronchial and lung malignant cancers might be caused by factors related to diet, lifestyle, cigarette smoking, and air pollution, among others. Given that the higher the age, the higher the relative incidence, it is recommended that individuals receive regular examinations for early detection and early treatment. Based on the cancer prescription patient study data collecting from the National Health Insurance Administration database from January to December 2016 under the data range of bronchial and pulmonary malignancies and by means of data exploration techniques of SOM and k-means, this study aimed to explore the patient group analysis.

Patients with cancer prescription were included in the study, which was conducted through data exploration of SOM to determine the clusters of patients after data pretreatment. The results could help us to understand where patients will fall in terms of age group, gender, and medical expenses. Malignant tumor is a common disease that threatens human life. With the wide range of malignant tumors as well as the different parts of the body that are affected, the number of patients will also be various. Finally, this research used k-means algorithm in data exploration to identify the significant relationship between both age group and sex of patients and both bronchial and pulmonary malignancies, and medical expenses. The analysis of cancer prescription and gender, age group and medical costs could be clearer from the results of this study. However, because the definition of the severity of the disease is different, the analysis of medical costs also varies. In the future, if combined with the database of National Health Insurance Administration and cancer registration file, it is recommended that a further investigation be conducted to understand the degree of differentiation of malignant tumors, the severity of each site of the body, and related medical resources.

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Appendix-I

Cluster	Gender	Age	Medical Items	Cost
		50~54	Average Total Declares Expense	$279, 233
			Average Surgery Expense	$38,117
		55~59	**Average Ward Fee**	**$109, 177**
cluster-1	**male**	60~64	Average Cost of Pharmacy Services	$4,708
			Average Cost of Drugs	$72,472
		65~69	Average Anesthesia Fee	$18,688
		75~79	Average Special Material Cost	$47,090
		50~54	Average Total Declared Expense	$1,093,606
			Average Cost of Drugs	**$306,776**
			Average Special Material Cost	$86,617
cluster-2	**female**		Average Ward Fee	$290,180
		55~59	Average Cost of Pharmacy Services	$10,055
		60~64	Average Anesthesia Fee	$59,459
			Average Surgery Expense	$91,209
		85~89	Average Total Declared Expense	$70,657
		70~74	**Average Surgery Expense**	**$27,460**
cluster-3	**female**	75~79	Average Anesthesia Fee	$11,365
		80~84	Average Cost of Drugs	$13,595
		85~89	Average Cost of Pharmacy Services	$3,385
			Average Ward Fee	$20,348
		65~69	Average Total Declared Expense	$707,059
		50~54	Average Special Material Cost	$51,668
		60~64	Average Surgery Expense	$42,073
cluster-4	**male**	65~69	Average Cost of Pharmacy Services	$6,740
			Average Cost of Drugs	**$301,788**
		75~79	Average Anesthesia Fee	$25,799
		85~89	Average Ward Fee	$230,394
		60~64	Average Total Declared Expense	$101,754
		65~69	Average Cost of Pharmacy Services	$2,640
			Average Cost of Drugs	$76,480
cluster-5	**female**		Average Special Material Cost	$36,262
			Average Anesthesia Fee	$23,779
			Average Surgery Expense	$38,337
			Average Ward Fee	**$124,140**
		65~69	Average Total Declared Expense	$61,068
		55~59	**Average Surgery Expense**	**$29,902**
		60~64	Average Anesthesia Fee	$11,382
cluster-6	**male**		Average Ward Fee	$18,312
			Average Special Material Cost	$2,545
			Average Cost of Pharmacy Services	$1,098
		70~74	Average Cost of Drugs	$7,918
		65~69	Average Total Declared Expense	$395,265
			Average Cost of Drugs	$32,948
			Average Special Material Cost	$45,808
cluster-7	**male**		Average Anesthesia Fee	$59,459
			Average Surgery Expense	**$91,209**
			Average Ward Fee	$87,420
		70~74	Average Cost of Pharmacy Services	$2,075

Table 3. Medical Expenses of Bronchia and Pulmonary Cancer Group by K-Means Cluster

International Journal of Management, Economics and Social Sciences
Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017)
2018, Vol. 7(S1), pp.13 – 25.
ISSN 2304 – 1366
http://www.ijmess.com

Employee Perceptions of Service Quality Based on Hospital Quality Improvement Strategy

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Following reforms in the Taiwanese healthcare system, hospitals are facing an increasingly competitive healthcare market. Hospital administrators, in response to this competition, are placing increasing importance on improving the quality of healthcare in order to ensure patient satisfaction. How can service quality (SQ) be improved in healthcare settings? This study explored how total quality management (TQM) influences employee perceptions of SQ. A cross-sectional study was performed, for which a sample was drawn from five regional hospitals in central Taiwan. This study used questionnaires to investigate employee perceptions of TQM and SQ in five regional teaching hospitals in Central Taiwan. A total of 300 questionnaires were distributed, of which 226 valid questionnaires were returned. The findings of this study revealed that TQM influenced employee perceptions of SQ. Therefore, hospital managers should use TQM strategy to influence employee perceptions of SQ. When promoting a TQM strategy, hospital managers should develop a clear vision for quality management within their organizations combined with distinct quality improvement policies and initiatives.

Keywords: Total quality management, service quality, quality improvement, healthcare management

As a result of the changing medical environment in Taiwan, hospitals are under increasing competitive pressure. To survive in this environment, hospital managers are enhancing the quality of service delivered to patients (Tsai and Tang, 2008). Healthcare quality improvement has also been a crucial issue for American hospitals (Izumi, 2012). Underlying these developments is an important question: how can healthcare quality be improved for patients? Researchers believe that healthcare organizations, when faced with an increasingly competitive market, can use total quality management (TQM) to lower the cost of healthcare and, at the same time, obtain customer satisfaction (Masters and Masters, 1993).

Many studies have confirmed the impact of TQM on the performance of organizations (e.g., Samsona and

Manuscript received May 20, 2017; revised September 19, 2017; accepted October 28, 2017.
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Terziovskib, 1999; Kaynak, 2003; Kannan and Tan, 2005). Most of the research on TQM, however, has been in the manufacturing sector (Long, 2003) with very little focused on service providers (Saravanan and Rao, 2006). As markets grow more competitive, service organizations have begun to value the importance of providing quality service to customers. Consequently, service quality (SQ) has become one of the performance targets service organizations are pursuing. For service organizations in the health care sector, such as hospitals, providing quality health care to patients has become an important objective, but few studies have explored the effect of TQM strategy on hospital performance.

Therefore, the current study assesses whether TQM can be used to help healthcare organizations control costs, pursue high standards of care, and ensure customer satisfaction simultaneously. It also investigates the influence of a hospital quality improvement strategy on employee perceptions of SQ. Results of this study can provide hospital administrators with a useful management tool to influence employee perceptions of SQ.

LITERATURE REVIEW

Modern healthcare is patient-centered; it must be customized to meet the needs of patients with a wide array of physiological conditions and illnesses. Patient-centered healthcare refers to the therapeutic relationship between healthcare providers and recipients of healthcare services, with an emphasis on meeting individual patient needs to accomplish patient satisfaction (Dabney and Tzeng, 2013). SQ is one of the most important factors in patient satisfaction. Recognizing this, hospital administrators have begun to promote health care quality policies to raise the quality of healthcare in their institutions, reduce the frequency of careless mistakes, and improve the efficiency of healthcare services (Arndt and Bigelow, 1996; Gillam and Siriwardena, 2013).

TQM is defined as a set of procedures used to reduce variations from a service-delivery or production process in order to improve efficiency, reliability, and quality (Steingrad and Fitzgibbons, 1993). Motwani (2001) asserts that TQM is a management strategy. It can be seen as a strategy with executive management commitment as the foundation and four pillars: process management, quality measurement and control, employee training, and customer focus. TQM can be employed by hospital administrators who are interested

in improving both the quality of the service process and its efficiency simultaneously. Studies confirm that increasing attention is being paid to the quality of hospital processes with the aim of improving productivity and cost-effectiveness (Hiidenhovi *et al.,* 2002). In addition to healthcare cost and efficiency, quality is another important indicator of hospital performance (Kenagy *et al.,* 1999). In hospitals, health services and their consumers are linked by service-providing employees, such as doctors, nurses, dieticians, and physiotherapists (Nashrath *et al.,* 2011), and SQ is an evaluation of the overall quality of the service interaction between these personnel and patients (Parasuraman *et al.,* 1988). Hospital employees, then, are well-placed to judge the quality of service that they deliver to patients. The challenge is that service is by nature intangible, heterogeneous, and inseparable, rendering its quality difficult to measure (Büyüközkan *et al.,* 2011). In response to this dilemma, the authors propose five constructs that can be used to measure SQ: tangibles, reliability, responsiveness, assurance, and empathy (Araceli *et al.,* 2005). This study explores the influence of TQM on employee perceptions of SQ.

METHODOLOGY

-Setting and Sample

A cross-sectional study was performed to investigate employee perceptions of TQM and SQ in five regional teaching hospitals in Central Taiwan. The method of sample selection was convenience sampling; the instrument used was a questionnaire. Respondents who were not acquainted with the researchers included administrative, medical, medical-technology, and nursing staff. The survey period was from November 1, 2009 to December 31, 2009. A total of 300 questionnaires were distributed, of which 226 valid questionnaires were returned.

After distributing the questionnaires, researchers informed subjects that responses would be used for research purposes only. Subjects agreed to these conditions and completed the questionnaires. Responses to all questions were anonymous.

-Sample Distribution

Among respondents, there were more females than males, with 203 females (89.8%) vs. 23 males (10.2%). A majority of respondents were from the administration (44.2%) and nursing (37.2%) departments. A majority of respondents (37.2%) had a seniority of 2-3 years, while 31.0% had a seniority of more than 8 years. Also

in the sample, a majority of respondents (62.4%) had some university education, while college graduates (22.1%) comprised the next largest group. A majority (47.3%) were 20-29 years of age, while 28.3%. were 30-39 years of age. A majority were frontline hospital workers (80.5%), while first-line managers comprised 10.6% (Table 1).

Demographics	Number	%
Gender		
Female	203	89.8
Male	23	10.2
Department		
Administration	100	44.2
Medical	33	14.6
Medical technology	9	4.0
Nursing	84	37.2
Age		
20-29	107	47.3
30-39	64	28.3
40-49	41	18.1
Over 50	14	6.2
Education Background		
High School	8	3.5
College	50	22.1
University	141	62.4
Master and PhD	27	11.9
Position		
Frontline employee	182	80.5
First line manager	24	10.6
Middle manager	5	2.2
Top manager	7	3.1
Others	8	3.5
Seniority		
Below 1 year	31	13.7
2-3 years	84	37.2
4-5 years	25	11.1
6-7 years	16	7.1
Over 8 years	70	31.0

Table 1. Participant Demographics (n=226)

-Data Collection Instruments

We referred to the TQM concept proposed by Motwani (2001) to design the questionnaire items. Respondents specified their level of agreement with 19 items using a five-level Likert scale: strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree.

To measure SQ, researchers used SERVQUAL, a self-reporting instrument with previous applications in the healthcare sector (Vartiainen, 1997; Hiidenhovi *et al.,* 2002). Respondents were asked to respond to 22

items on a five-point Likert Scale, ranging from 1= "very unimportant" to 5= " very important." In most studies of SQ, customers have served as subjects, with an emphasis on understanding these customers' perception of SQ after a service was delivered. Tsai and Wu (2010), however, utilized hospital nurses as subjects, drawing on nurses' perceptions to measure SQ. The current study used an approach similar to Tsai and Wu (2011) to define SQ, relying on employee rather than customer perceptions.

Because the primary language of respondents was Mandarin Chinese, the author translated the Motwani (2001) questionnaire from English to Chinese. The Chinese questionnaire was then translated back to English to ensure semantic coherence. After translation, the director of a regional hospital's healthcare quality department and two medical university professors with hospital management experience were invited to evaluate the questionnaire for expert validation. Then, fifty staff members of a regional hospital participated in the pilot study, for which the Cronbach's α was 0.947 for TQM and 0.952 for SQ. All Cronbach's coefficients exceeded 0.70, which was considered acceptable (DeVellis, 2011). According to the Bartlett test, the P value of TQM in this study was 0.000 and the P value of SQ was 0.000.

The data were analyzed with SPSS 20.0 using descriptive statistics to characterize the demographics of the sample. To understand the relationships between demographic characteristics of participants and their perceptions of TQM and SQ, a one-way ANOVA was conducted with equal variance assumed. A Scheffe post-hoc comparison, focusing on results with statistically significant differences, was also performed. Furthermore, linear regression was used to test the impact of TQM on SQ, and a Pearson correlation test was conducted to determine the relationship between the constructs of TQM and SQ. The Cronbach's α obtained from the reliability analysis of the 226 valid questionnaires was 0.936 for TQM and 0.973 for SQ.

RESULTS

The mean of TQM was between 3.83 and 4.20. The mean of SQ was between 3.91 and 4.41. The standard deviation of TQM was between 0.604-0.788, while the standard deviation of SQ was between 0.581-0.784 (see Appendix-I).

A One-Way ANOVA was used to analyze how demographics influenced TQM and SQ. It was found that medical department employees were less aware of TQM than medical technology and nursing department

employees (F value=2.603, P value=0.053). Department of employment also influenced perception of SQ. Medical technology, administration and nursing department staff reported greater awareness of SQ than medical department staff (*f* value=5.541, *p* value=0.001). Occupation also influenced perception of TQM (*f* value=3.116, *p* value=0.016) but had no impact on perception of SQ (*f* value=1.483, *p* value=0.208). Overall, middle and first-line managers' awareness of TQM was greater than that of frontline employees (*f* value=3.116, *p* value= 0.016).

Employee seniority did not have a significant impact on perception of TQM (F value=1.558, *p* value=0.187) and SQ perception (*f* value=1.699, *p* value=0.151). Educational background had a significant impact on perception of TQM (*f* value=2.260, *p* value =0.082) and a non-significant impact on perception of SQ (*f* value=0.747, *p* value=0.525). Employees with Masters or PhDs had greater awareness of TQM than employees with only college degrees. Employee age had a significant impact on perception of TQM (*f* value=2.178, *p* value=0.092) and a non-significant impact on perception of SQ (*f* value=1.808, *p* value=0.147). Employees aged 40-49 were more aware of TQM than those aged 30-39 (Table 2).

Dependent Variables	Independent Variables	*f* value/*t* value (*p* value)	Scheffé's post hoc
Total Quality Management	Gender	2.194(0.029*)	Male>Female
	Department	2.603(0.053 †)	Nursing>Medical, Medical technology>Medical
	Age	2.178(0.092 †)	40-49>30-39
	Education Background	2.260(0.082 †)	Master and PhD>College
	Position	3.116(0.016*)	Middle manager>Frontline employee, First line manager >Frontline employee
	Seniority	1.558(0.187)	
SQ	Gender	0.276(0.783)	
	Department	5.542(0.001***)	Administration>Medical, Medical Technology>Medical, Nursing>Medical
	Age	1.808(0.147)	
	Education Background	0.747(0.525)	
	Position	1.483(0.208)	
	Seniority	1.699(0.151)	

Note. †$p<.10$ *$p<.05$ **$p<.01$ ***$p<.001$

Table 2. One-Way ANOVA and Scheffé's Post Hoc Analysis

Due to the number of variables involved, an exploratory factor analysis was used to reduce the TQM and SQ constructs. Kaiser (1974) maintained that when the Kaiser-Meyer-Olkin value exceeds 0.90, a factor analysis can be undertaken. For this study, TQM had a KMO score of 0.947, while SQ had a score of 0.946, indicating that TQM and SQ were both suitable for factor analysis. Maximum likelihood estimation was used to extract the factor and the varimax method for factor rotation.

It was found that the two TQM constructs according to each construct' s characteristics were quality policy and initiatives and customer-centeredness. It was found that the three SQ constructs according to each construct' s characteristics were reliability and assurance, empathy, and tangibles (Appendix-I). Linear regression was used to test the impact of TQM on SQ. We obtained P value=0.000, β =0.418, and R^2=0.175. Thus, TQM had a positive influence on SQ. In addition, a Pearson correlation was used to test the relationship between the constructs of TQM and SQ. The TQM quality policy and initiatives construct, the SQ tangibles construct, and related coefficients yielded the rather high prime number of 0.445 (P=0.000). The TQM' s customer centeredness construct, SQ tangibles construct, and related prime number quality were also quite high at 0.354 (P=0.000) (Table 3). All constructs of TQM were positively correlated with all constructs of SQ.

	Quality Policies and Initiatives ***β***	**Customer Centeredness** ***β***	**Reliability and Assurance** ***β***	**Empathy** ***β***	**Tangibles** ***β***
Quality Policies and Initiatives	1	0.742**	0.353**	0.346**	0.445**
Customer Centeredness	0.742**	1	0.306**	0.312**	0.354**
Reliability and Assurance	0.353**	0.306**	1	0.757**	0.682**
Empathy	0.346**	0.312**	0.757**	1	0.543**
Tangibles	0.445**	0.354**	0.682**	0.543**	1

Note. †p<.10 *p<.05 **p<.01 ***p<.001

Table 3. The Correlation Analysis between TQM and SQ

DISCUSSION

TQM is a comprehensive organizational strategy and philosophy. Healthcare quality management should simultaneously consider structure, process, and results (Donabedian, 1980). This study explores TQM (as an organizational structure factor) and SQ (as a result) and at the same time analyzes the correlation

between the TQM strategy and SQ. The study finds that TQM and SQ are positively correlated. These results can help hospital managers understand that when a hospital employs a TQM strategy to implement its quality management policy, there is a positive impact on employees' perceptions of SQ.

In this study there are also notable disparities in TQM awareness among different departments' staff. For example, nursing and medical technology department staff have greater awareness of TQM than staff in the medical department. Managers' awareness of TQM also differs notably from non-managers' awareness, in that managers demonstrate greater awareness of TQM than frontline staff. Furthermore, males have greater awareness of TQM than females, and those with Masters and PhDs have greater awareness of TQM than those with only college degrees. Based on these results, it may be advantageous for hospital managers to design educational and training programs for all employees, regardless of role, gender or educational background, to advance their organization's vision of TQM.

Disparities in SQ perception are also noted among employees from different departments. Medical technicians, nurses and administrators demonstrate greater awareness of SQ than those in the medical department. This is perhaps because doctors' workloads are comparatively greater. They must manage teaching, service, and research simultaneously (Nuckols *et al.,* 2009). In addition, being on-call and working long hours can take a toll on doctors (Drolet *et al.,* 2017) causing them to neglect the importance of SQ compared to staff in other departments. It is recommended that hospital managers start by lessening doctors' workload, reducing their work-related pressures, and fostering in them a greater awareness of SQ.

Hiidenhovi *et al.* (2001) maintain that healthcare organizations, while pursuing improvements in SQ, should aim to make patients the center of SQ. The construction of the SQ instrument was a logical process of consecutive stages that took several years. It was developed to measure patients' perceptions of the quality of service provided by outpatient department staff. Because employees are the vehicle through which healthcare is delivered to patients, employee behavior can influence patients' perception of healthcare quality. In order to understand employee perception of healthcare, this study uses hospital employees as subjects. The study finds that TQM can positively influence employees' SQ perception, lending support to the hypothesis put forward by Hiidenhovi *et al.* (2001).

CONCLUSION

Due to changing policies in the healthcare sector, hospitals must improve internal management capacities to sustain competitive advantage. Scholars believe TQM is the best management strategy for organizations to meet the demands of a competitive market (Motwani, 2001). SQ is often used by scholars as a measure of an organization's performance. This study is an empirical investigation of the influence of hospital management strategies (TQM) on management performance (SQ). The findings are that TQM strategy can positively impact employee perceptions of SQ. It is suggested that hospital managers use TQM policy to influence the employee perceptions of SQ. When promoting a TQM strategy, hospital management should develop a clear organizational vision for quality management and combine it with distinct quality improvement initiatives.

LIMITATIONS AND FUTURE DIRECTIONS

This study focused on five regional teaching hospitals in Central Taiwan, potentially limiting the generalizability of results, though a cross-sectional methodology was used. The attitude and behavior of employees or the implementation of a motivation policy could influence the quality of the services that employees provide to patients, which also means that, over time, SQ could change. With sufficient time and budget, future studies could use longitudinal data to track the effectiveness of TQM and quality improvement activities of hospitals over time.

This study sample was comprised of five kinds of hospital employees, and perceptions of SQ belong solely to these groups of respondents. In other words, we did not take into account the perceptions of SQ of the patients themselves. According to the concept of the SQ gap, there may have been a difference between staff and patient perceptions (Tsai and Wu, 2011), and therefore, we suggest that future studies use patients in the study samples to explore SQ. Kenndy *et al.* (2011) found when hospital managers link compensation with employee performance, it may improve the employee' s perception of SQ. Thus, we suggest that future research explore the impact of compensation on SQ.

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Appendix-I

Factor Naming (Pattern Matrix) and Reliability Analysis Results

No.	Content of items / constructs / scales	Mean	SD	Factor Loading	Variance Explained (%)	Cronbach's α
	TQM					0.957
	Customer Centeredness				47.225	
18	Our hospital has an open and trusting organizational culture.	3.83	0.723	0.809		
16	In order to improve healthcare quality, our hospital collects and analyzes customer data and information.	3.88	0.668	0.684		
19	The employees at our hospital know that providing healthcare to customers is one of our hospital's goals.	3.92	0.716	0.664		
2	The employees at our hospital are actively involved in quality-improving activities.	3.88	0.717	0.658		
15	Our hospital avoids waiting time on internal service processes.	3.88	0.818	0.519		
3	The employees at our hospital are committed to quality-improved activities.	3.77	0.768	0.499		
1	Our hospital provides a supportive environment to implement the total quality management.	3.86	0.614	0.494		
4	The employees at our hospital have authority to design and to finish their work.	3.90	0.642	0.482		
6	Our hospital provides the training of total quality management to employees.	4.15	0.734	0.466		
	Quality Policies and Initiatives				3.327	
9	Customer satisfaction is our hospital's goal.	4.20	0.604	0.683		
10	Our hospital improves and develops its relationship with customers for a long-term goal.	4.12	0.648	0.658		
11	Our hospital knows the customer's healthcare needs and wants.	3.94	0.681	0.620		
7	The work teams at our hospital are asked to coordinate and communicate with each other.	4.01	0.686	0.618		
12	For customer satisfaction, our hospital is looking for a method to improve services.	4.05	0.694	0.613		
13	Our hospital emphasizes how to improve the service value for customers.	3.97	0.653	0.608		
14	In order to improve SQ, our hospital improves the employees'	4.01	0.693	0.605		

No.	Content of items / constructs / scales	Mean	SD	Factor Loading	Variance Explained (%)	Cronbach's α
	service skills.					
8	Our work teams are asked to use innovative methods to work.	3.85	0.788	0.509		
17	There is a clear vision, long-term planning and quality policy in our hospital.	4.05	0.662	0.508		
5	The employees at our hospital knows what our hospital's philosophy and objectives are.	3.95	0.697	0.422		
	SQ					0.978
	Reliability and Assurance				52.570	
15	Provide safety experience during the medical services.	4.40	0.598	0.836		
14	Medical Staffs' behaviors build patients confidence to medical services.	4.34	0.620	0.723		
16	Medical Staffs were being politeness to patients.	4.39	0.611	0.705		
10	Medical Staffs should inform patients the service contents.	4.35	0.600	0.697		
11	Medical Staffs should help patients immediately.	4.31	0.634	0.670		
17	Medical Staffs are capable to answering patients' questions.	4.41	0.592	0.664		
12	Medical Staffs are highly willing to service patients.	4.28	0.646	0.588		
6	Do its best to help patients resolve problems.	4.36	0.581	0.511		
7	Do the right thing the first time.	4.33	0.639	0.494		
9	Keep records on do not make mistakes.	4.22	0.689	0.418		
	Empathy				5.643	
20	Medical Staffs provide proper services to different patients.	4.26	0.645	0.783		
22	Medical Staffs should know different patients have different needs.	4.34	0.655	0.755		
21	Patients' benefit is the first priority.	4.27	0.636	0.729		
19	Set up proper service executive time according to different patients'' needs.	4.16	0.640	0.707		
18	Provide proper care to different patients.	4.28	0.609	0.529		
8	Provide services to patients on time.	4.30	0.617	0.508		
13	Medical Staffs were not too busy to ignore patients.	4.25	0.640	0.489		
	Tangibles				3.977	
3	The staffs in the hospital keep appearances clean	4.34	0.628	0.810		
4	Perfect services and service explanation.	4.34	0.649	0.702		
5	Executed commitment to patients on time.	4.28	0.651	0.631		
1	The hospital has modern equipment.	4.15	0.676	0.609		

No.	Content of items / constructs / scales	Mean	SD	Factor Loading	Variance Explained (%)	Cronbach's α
2	The hospital has modern building exterior.	3.91	0.784	0.561		

International Journal of Management, Economics and Social Sciences
Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017)
2018, Vol. 7(S1), pp.26 – 39.
ISSN 2304 – 1366
http://www.ijmess.com

Exploring the Gender Difference in Fear of Crime among Older People

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The purpose of this study was to evaluate anew fear of crime scale that accurately reflects the current criminal experiences of older people and test gender differences in fear of crime in a number of items, in the item wording, and in choice response categories. A series of chi-square tests compared the fear of crime scale of older people according to their gender, and then logistic regression models were created and tested between males and females. The finding presents the odds ratios, which suggest that older female odds were 168% higher than older men odds of the item 'Someone forcibly taking your property'. They were 43% lower than older men odds of the item 'Some strangers wandering around your home at midnight' and were 170% higher than older men odds of the item 'Some drag racing adolescents trying to hurt you'. Odds were 141% higher in older women than in older men of the item "Someone trying to abduct you". In conclusion, older women are more afraid of crime than older men. This study suggests that the fear of crime in older women focuses more on bodily injury than in property damage.

Keywords: Older people, fear of crime, gender difference

The high level of fear of crime may create a higher risk to the overall quality of life to those who are vulnerable, especially older people. In the fear of crime literature, numerous studies of older people have been published in the last 3 decades. Some older people feel vulnerable and unable to protect themselves physically or economically [14]. Some people perceive their environment to be threatening [20; 28]. Older people usually are aware of the potential for crimes; however, they often lack the ability to prevent crime, largely because of their own physical limitations.

With regard to the fear of crime, older people are more afraid of crimes against their person than crimes against their property [30]. McKee and Milner [19] assessed 60 community-dwelling older people, aged 65 and over, in Sheffield, and found that older people had more fear of personal crime (e.g., mugging, assault, rape and murder) than property crime (e.g., burglary, car theft, vandalism and shoplifting). They also had more fear of the possibility of crime than the reality of crime. Just the fear of crime alone may be a causal factor in reduced activity, thus leading to poor quality of life among older people. Previous research has

Manuscript received May 20, 2017; revised September 16, 2017; accepted October 28, 2017.
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demonstrated that fear of crime is associated with lower morale, lower subjective well-being, and reduced neighborhood satisfaction [28]. Smith et al. [25] also concluded that being a victim of crime directly, and indirectly, affects older people' s quality of life.

The past thirty years of research into the relationships between gender and fear has shown that women are more afraid of crime or becoming a victim of crime. Paradoxically though, women are far less likely to be the victims of crime [18; 22]. In addition to the fear women perceive when coming into bodily harm, women also fear the inability to resist the act of crime when it occurs. These emotional perceptions of powerlessness lead to an increase in the fear of crime [8].

There are four main explanations for men's reactions to crime. First, society doesn't portray men as victims but rather the protectors of women, especially women at risk [22]. After men get married they feel a responsibility to play the male protector role for their wives, in part to better conceal their own fears [21]. Second, society's expectations of the masculine role model: men learn that fear of crime cannot be shown, not even in small doses, as it would detract from their own masculinity [27]. Third, men can be afraid of crime, but only in special circumstances, such as the elevated anxiety of being a stranger in a new city [24]. Fourth, men are not actually afraid for themselves, but for other people's welfare. This phenomenon is called "altruistic fear". Research conducted by Warr and Christopher [29] found that men are more fearful for their wives then for themselves.

Most of the current research shows that women fear crime more than men, despite the fact that there are differences in men's and women's fears related to crime [17; 23]. These differences between the genders maybe explained as different levels of extent of the fear of crime. Franklin and Franklin found in their research that women's fear of crime decreased with increasing age [11]. The level of Men's fear of crime did not vary with age, but it did with income. Men with higher incomes are more afraid of crime. In another study into the fear of crime between the genders, Snedker [26] found that both men and women both fear the crime of physical assault the most, but there is less evidence to support that women have an especially high fear of rape [26].

In the previous sections, the author reviewed the literature and its' examination of many facets affecting gender differences on fear of crime. Most studies are based on a single question to measure fear of crime for example; "How safe do you feel walking alone in this area after dark?" [3; 5]. Whilst this may not tap fully the emotional dimensions of fear, it has been the method adopted in most researches. However, multiple-item indices are also not a panacea for social measurement. Unless properly constructed and tested, one cannot be assured that composite indices and measurement scales possess appropriate psychometric properties [16]. Ferraro and LaGrange [9] make a distinction between 'formless' and 'concrete' fears. These discreet fear types cannot be measured by asking a single question. As the review demonstrates, fear of crime gender differences are affected by multiple variables. The purpose of this study is to evaluate anew fear of crime scale that accurately reflects the current criminal experiences of older people and test gender differences of fear of crime in the number of items, in the item wording, and in choice response categories.

METHODS

-Ethics and Participants

This study was approved by the University Research Committee, Kainan University. Participants were informed about the study's purpose, their anonymity and the confidentiality of their individual data. Participants were advised of their right to withdraw from the research study by simply failing to complete the questionnaire.

The purposive sample was taken from a community in Taoyuan Taiwan from April to June 2011. The inclusion criteria of recruiting the participants in this study were as follows: (1) community-dwelling residents; (2) aged over 65 years; and (3) having ability to answer questionnaire. The participants who had a diagnosis of dementia or substance abuse were excluded. A total of 200 participants filled and completed the structured questionnaire survey. Data from participants who did not fully complete the questionnaire was excluded from the study (n = 24). Data from totally completed questionnaires of the remaining 176 participants included 89 (50.6%) male and 87 female (49.4%). Participants ranged from 65 to 83 years of age with a mean age of 70.73 years.

-Measures

Several socio-demographic characteristics including age, gender, marital status, education, religion, and living arrangement were controlled. Age was coded into two dummy variables: 65-70 years old = 1 and 70+ = 0 (reference category). Gender was dummy-coded as male = 1 and female = 0 (reference category). Marital status was dichotomized as married = 1, unmarried = 0 (single, divorced, widowed or separated; reference category). Education was dummy-coded as literate = 1 and illiterate = 0 (reference category). Religion was dichotomized as having a religion = 1 and no religion = 0 (reference category). Living arrangement was coded into two dummy variables: living with others = 1 and living alone = 0 (reference category). For purposes of this study, all these socio-demographic characteristics were controlled.

The original Chinese fear of crime scale (Cronbach α =0.9) was developed by Professor Hsieh [13]. The 20-item fear of crime scale uses 10-point Likert response format ranging from strongly disagree (1) to strongly fearful (10). Higher scores indicate very high level fear in relation to crime. Although the fear of crime scale has been applied to Chinese people in general to test fear of crime; unfortunately, published psychometric data on the use of the fear of crime scale in older people could not be found that was specific to the Taiwanese population.

The fear of crime scale contained 20 items, was of the 10-point Likert type, and ranged from not being fearful at all to being extremely fearful. In this study, repeated exploratory factor analysis (EFA) and Cronbach's [7] reliability tests were performed to purify measure and to refine scale as first-order analysis. The data was suitable for factor analysis (KMO = 0.873, Bartlett's test of sphericity = 2340.955, df = 171, p< .001)). Dimensions were interpreted if the item loaded on the dimension at 0.4 or above. However, only item 9 had a factor loading value below 0.4; most of the coefficients are higher or closer to the benchmark of 0.4 Thus, item 9 was dropped from the scale and the results revealed a clear pattern of item loading across the two factors named 'concrete fear' and 'formless fear' and satisfied Kaiser's [15] eigenvalue criterion. An alpha score of 0.7 or greater is generally considered to be an acceptable reliability measure for research [6]. The Cronbach's reliability tests were show on the

fear of scale (19 items) was 0.923, factor 1 was 0.930, and factor 2 was 0.817 as the Table 1. The alpha values of scale reliability resulted in acceptable levels of internal consistency.

	Factor Item	F1	F2
F1 (concrete fear)			
1	Someone threatening you with a weapon	.865	.080
3	Someone forcefully taking your property	.819	.148
4	Someone defrauding you of your money	.570	.409
5	Someone trying to assault you	.617	.126
7	Someone trying to murder you	.599	.018
10	Being sold contaminated food (toxic substances)	.518	-.011
11	Someone breaking in your home when you are not at home	.510	.452
12	Someone whom you know beating you	.818	.130
13	Your car or motorcycle being stolen	.592	.334
14	A drunken driver injuring you	.800	.179
16	Someone breaking in your home when you are at home	.710	.152
17	Some drag racing adolescents trying to hurt you	.844	.131
18	Someone robbing you when you withdraw money	.579	.448
19	Someone try to set fire your property	.567	.334
20	Someone trying to abduct you	.866	.095
F 2 (formless fear)			
2	Someone making harassing phone calls	.085	.746
6	Some beggars trying to approach to you	.045	.809
8	Some strangers wandering around your home at midnight	.079	.762
15	Some adolescents loitering around your home	.141	.844
Eigenvalues		7.329	3.442
Percentage of variance		38.58%	18.12%
Cumulative percentage of variance		38.58%	56.70%
Cronbach's Alpha		.930	.817

Table 1. Factor Loadings for the Fear of Crime Items

A confirmatory factor analysis (CFA) was produced that examined the validity of the fear of crime scale. The criteria of good-fit-index were (1) the relative chi-square criterion for acceptance ranging from more than 2 to less than 5 [2]; (2) comparative fit index, CFI) was > 0.9 [1]; (3) the incremental fit index (IFI) was > 0.9 for avoiding the underestimation of fit in small samples [2]; and (5) the root mean square error of approximation (RMSEA) values ≤ 0.05 as a good fit; 0.0 5-> 0.08 as an adequate fit; 0.08-0.10 as mediocre fit; and > 0.1 indicating not acceptable [4]. The loadings of the items on their respective factors in the model range from 0.45 to 0.88 with all being significant at the 0.05% level (Table 2). Standardized estimates for fully model were χ^2 = 699.85 (p< .001, χ^2/df = 4.63); CFI = 0.9;

IFI = 0.9; PGFI = 0.6; and RMSEA = 0.14 (90% CI = 0.13 – 0.15). Not surprisingly, the chi-square was significant; the model therefore is regarded as unacceptable. However, the relative chi-square for the study was 4.63 which did fit the study criterion of less than 5 [27]. Although chi-square and the RMSEA were somewhat below expectation, the relative chi-square, CFI, IFI, and PGFI were indicative of reasonable model fit in this sample.

	Factor Item	λ	E	*t*
F1	(concrete fear)			
1	Someone threatening you with a weapon	.85	.28	13.82*
3	Someone forcibly taking your property	.82	.33	13.05*
4	Someone defrauding you of your money	.63	.60	9.17*
5	Someone trying to assault you	.59	.65	8.43*
7	Someone trying to murder you	.55	.70	7.69*
10	Being sold contaminated food (toxic substances)	.45	.80	6.14*
11	Someone breaking in your home when you are not at home	.60	.64	8.51*
12	Someone whom you know beating you	.82	.33	13.02*
13	Your car or motorcycle being stolen	.63	.61	9.05*
14	A drunken driver injuring you	.80	.36	12.68*
16	Someone breaking in your home when you are at home	.70	.51	10.42*
17	Some drag racing adolescents trying to hurt you	.84	.30	13.52*
18	Someone robbing you when you withdraw money	.64	.59	9.37*
19	Someone trying to set fire to your property	.61	.63	8.68*
20	Someone trying to abduct you	.85	.27	13.97*
F2	(formless fear)			
2	Someone making harassing phone calls	.68	.54	9.45*
6	Some beggars trying to approach to you	.74	.45	10.58*
8	Some strangers wandering around your home at midnight	.61	.63	8.26*
15	Some adolescents loitering around your home	.88	.22	13.39*

* $p < .05$

Table 2. Measurement Model

The reliability in CFA was measured by the CR for two factors were 0.93 (concrete fear) and 0.82 (formless fear) as shown in Table 3. In this study, AVE ranged were 0.50and 0.54and did match the recommended threshold of 0.5 [10]; however, Hair et al. [12] suggested that CR>AVE, MSV<AVE, and ASV<AVE. In this study, all indices matched this criterion, indicated good convergent validity for each construct, and also support discriminant validity. Based on these evidences for reliability, convergent and discriminant validity, the measurement model was deemed acceptable. The fear of crime scale was dummy-coded as very fearful = 1 and slightly fearful = 0 (reference category) by mean.

	Variance and Reliability						Factor Correlations*	
					Convergent Validity	Discriminant Validity		
	CR	AVE	MSV	ASV	CR>AVE AVE>.5	MSV<AVE ASV<AVE	Concrete fear	Formless fear
Concrete fear	.93	.50	.14	.14	Yes	Yes	**.96**	
Formless fear	.82	.54	.14	.14	Yes	Yes	.38	**.91**

* Square root of AVE in bold on diagonals

Table 3. Results of Reliability, Convergent and Discriminant Validity

RESULTS

Table 4 presents the baseline numbers, percentages, means, and standard deviations data for age, gender, marital status, education, religion, living arrangement, and fear of crime scale of 176 participants. Participants were more likely to be male, married, having a religion, literate, and living with others.

Variables	N	%	Mean	SD
Age	176		70.73	3.802
Gender	176			
Male	89	50.6		
Female	87	49.4		
Marital status	176			
Unmarried	79	44.9		
Married	97	55.1		
Education	176			
Illiterate	52	29.5		
Literate	124	70.5		
Religion	176			
No religion	16	9.1		
Having a religion	160	90.9		
Living status	176			
Living alone	17	9.7		
Living with others	159	90.3		
Fear of crime scale				
1. Someone threatening you with a weapon	176		7.27	2.304
2. Someone making harassing phone calls to you	176		3.49	1.951
3. Someone forcibly taking your property	176		7.17	2.058
4. Someone defrauding you of your money	176		6.00	2.280
5. Someone trying to assault you	176		6.88	2.539
6. Some beggars trying to approach to you	176		3.57	2.334
7. Someone trying to murder you	176		7.53	2.783
8. Some strangers wandering around your home at midnight	176		4.12	2.306
9. Being sold contaminated food (toxic substances)	176		7.24	1.571

10. Someone breaking in your home when you are not at home	176	5.86	2.332
11. Someone that you know hitting you	176	7.59	2.370
12. Your car or motorcycle being stolen	176	5.86	2.177
13. A drunk driver injuring you	176	7.66	2.182
14. Some adolescents gathering around your home	176	4.24	2.349
15. Someone breaking in your home when you are at home	176	6.93	2.482
16. Some drag racing adolescents try to hurt you	176	7.99	2.265
17. Someone robbing you when you withdraw money	176	7.16	2.288
18. Someone trying to set fire your property	176	7.61	2.307
19. Someone trying to abduct you	176	8.74	2.232

Table 4. Descriptive Statistics of the Sample by Socio-Demographic Characteristics and the Fear of Crime

It can be seen from Table 5 that there was a significant gender difference in 'Someone forcibly taking your property' (χ^2=5.003; p=0.025), 'Some strangers wandering around your home at midnight' (χ^2=5.901; p=0.015), 'Some drag racing adolescents trying to hurt you' (χ^2=4.566; p=0.033), 'Someone trying to set fire your property' (χ^2=4.917; p=0.027), 'Someone trying to abduct you' (χ^2=4.553; p=0.033).

Variable	Female N (%)		Male N (%)		χ^2	*p*-value
Someone threatening you with a weapon						
Slightly fearful	13	(41.9)	18	(58.1)	0.846	0.358
Very fearful	74	(51.0)	71	(49.0)		
Someone making harassing phone calls						
Slightly fearful	76	(49.7)	77	(50.3)	0.027	0.869
Very fearful	11	(47.8)	12	(52.2)		
Someone forcibly taking your property						
Slightly fearful	8	(29.6)	19	(70.4)	5.003	0.025 *
Very fearful	79	(53.0)	70	(47.0)		
Someone defrauding you of your money						
Slightly fearful	32	(49.2)	33	(50.8)	0.002	0.967
Very fearful	55	(49.5)	56	(50.5)		
Someone trying to assault you						
Slightly fearful	15	(45.5)	18	(54.5)	0.257	0.612
Very fearful	72	(50.3)	71	(49.7)		
Some beggars trying to approach to you						
Slightly fearful	67	(48.9)	70	(51.1)	0.069	0.793
Very fearful	20	(51.3)	19	(48.7)		
Someone trying to murder you						
Slightly fearful	14	(46.7)	16	(53.3)	0.111	0.739
Very fearful	73	(50.0)	73	(50.0)		
Some strangers wandering around your home at midnight						
Slightly fearful	70	(55.1)	57	(44.9)	5.901	0.015 *
Very fearful	17	(34.7)	32	(65.3)		
Of being sold contaminated food (toxic substances)						
Slightly fearful	6	(35.3)	11	(64.7)	1.505	0.220
Very fearful	81	(50.9)	78	(49.1)		
Someone breaking in your home when you are not at home						
Slightly fearful	33	(46.5)	38	(53.5)	0.415	0.519
Very fearful	54	(51.4)	51	(48.6)		
Someone that you know hitting you						
Slightly fearful	14	(46.7)	16	(53.3)	0.111	0.739
Very fearful	73	(50.0)	73	(50.0)		
Your car or motorcycle being stolen						

Slightly fearful	36	(49.3)	37	(50.7)	0.001	0.979
Very fearful	51	(49.5)	52	(50.5)		
A drunk driver injuring you						
Slightly fearful	8	(33.3)	16	(66.7)	2.881	0.090
Very fearful	79	(52.0)	73	(48.0		
Some adolescents gathering around your home						
Slightly fearful	65	(49.2)	67	(50.8)	0.008	0.931
Very fearful	22	(50.0)	22	(50.0)		
Someone breaking in your home when you are at home						
Slightly fearful	20	(43.5)	26	(56.5)	0.883	0.347
Very fearful	67	(51.5)	63	(48.5)		
Some drag racing adolescents trying to hurt you						
Slightly fearful	7	(29.2)	17	(70.8)	4.566	0.033 *
Very fearful	80	(52.6)	72	(47.4)		
Someone robbing you when you withdraw money						
Slightly fearful	12	(35.3)	22	(64.7)	3.370	0.066
Very fearful	75	(52.8)	67	(47.2)		
Someone try to set fire your property						
Slightly fearful	11	(32.4)	23	(67.6)	4.917	0.027 *
Very fearful	76	(53.5)	66	(46.5)		
Someone trying to abduct you						
Slightly fearful	5	(26.3)	14	(73.7)	4.553	0.033 *
Very fearful	82	(52.2)	75	(47.8)		

* p <.05. ** p <.01. *** p< .001

Table 5. The Difference of Gender on Each Item of the Perception of Fear

A high proportion of older women verses older men felt very fearful of 'Someone forcibly taking your property', 'Some drag racing adolescents trying to hurt you', 'Someone trying to set fire to your property', and 'Someone trying to abduct you'. The older men reported being only slightly fearful of these potential threats.

A higher percentage of older men verses older women felt very fearful of 'Some strangers wandering around their home at midnight'. The older women reported to being only slight fearful of this potential threat.

Logistic regression was conducted to assess whether gender significantly predicted whether the type of crime made older people slightly fearful or very fearful. As can be seen in Table 6, the odds ratios and confidence interval for the item of 'Someone was forcibly taking your property' was 2.68 (95% CI=1.105− 6.504; p=0.029), for the item of 'Some strangers wandering around your home at midnight' was 0.433 (95% CI=0.218− 0.858; p=0.016), for the item of 'Some drag racing adolescents trying to hurt you' was 2.698 (95% CI=1.058− 6.880; p=0.038), for the item of 'Someone try to set fire to your property' was 2.408 (95% CI=1.092− 5.308; p=0.029), and for the item of 'Someone trying to abduct you' was 3.061 (95% CI=1.052− 8.908; p=0.040).

Table 6 presents the odds ratios, which suggest that older female odds were 168% higher than older men odds of the item 'Someone forcibly taking your property', were 43% lower than older men odds of the item 'Some strangers wandering around your home at midnight', were 170% higher than older men odds of the item 'Some drag racing adolescents trying to hurt you', and were 141% higher than older men odds of the item 'Someone trying to abduct you' .

Variable (reference category)	B	OR	95% CI	*p* value
Someone forcibly taking your property (very fearful)	0.986	2.680	1.105−6.504	0.029*
Some strangers wandering around your home at midnight (very fearful)	-0.838	0.433	0.218−0.858	0.016*
Some drag racing adolescents trying to hurt you (very fearful)	0.993	2.698	1.058−6.880	0.038*
Someone trying to set fire your property (very fearful)	0.879	2.408	1.092−5.308	0.029*
Someone trying to abduct you (very fearful)	1.119	3.061	1.052−8.908	0.040*

* p <.05. ** p <.01. *** p< .001

Table 6.The Difference of Gender on Selected Items of the Fear of Crime Scale

DISCUSSION

The research shows that older women are more afraid than older men for the following scenarios: someone seizing your property, being hit by reckless teenager drivers, house or vehicle arson, and abduction. Older men are more afraid than older women of strangers prowling around the house at night. In general, older women are more afraid of crime than older men. The founding of present study showed that the fear of crime in older women focuses more on taking property, hurting you, and abducting you.

The results of this study are consistent with previous related studies: women's fear of crime is significantly higher than men's [17; 23; 26]. The main reasons for this premise are given as follows: first, women's bodies are inherently physically weaker than men's and women have weaker self-defense skills [22]. This leads a woman to experience fear and anxiety for her personal safety and she has a heightened awareness of crime in order to avoid the threat of physical suffering, abuse and violence. Second, society overtly encourages men, but not women, to be brave and show no fear in the

face of danger [21]. Therefore women are more likely to show fear when facing a dangerous situation. If women have severe anxiety and they perceive that they will have a lack of emotional control in a dangerous situation then their overall fear of being a potential victim of crime will increase. Third, society has set expectations of gender and behavioral differences. Women in traditional Asian society are taught to obey, be gentle and avoid displaying any manly behavior [27]. These traditional female values lead women to form a victim's attitude in response to crime, such as feeling incompetent when presented with problems, and instills a serious fear of crime and a fear of becoming a victim of crime in the process. According to the material from the researchers, society teaches women to play a more passive and weaker role than that of men, rather than taking the initiative in social situations. In the event of a crisis, women feel an inability to deal with the situation, but instead display the emotions of panic, fear and worry. This can lead to a constant state of unease and fearfulness of being a victim of crime. Lastly, older men and women differ not only in the degree of fear of becoming a victim of crime but also in the nature of their fears. Women reflect more on personal safety concerns, while men tend to worry about themselves as well as their friends and family. After a man is married, he feels responsible for his wife's and family's protection, which is the male protector role. This traditional male role is also used to hide his own fears. Another element of difference in comparing the genders is that older men are more afraid than older women of strangers prowling around the house at night.

Previous research studies suggest that there are no gender differences when measuring fear of becoming a victim of a property crime [17]. The greatest contribution of this study is the contrary finding that significant gender differences of fear of property crime do exist. In this study, older women include financial loss in their fear of crime, which is probably related to their economic status. Taiwan's birth rate has decreased while the average female life expectancy has increased. 27% of women aged 65 or older have their own financial economic security, such as employment and investment income or retirement insurance. Up to 58% of older women rely on their children for support in Taiwan. If the family's property were lost, the living conditions of older women would be seriously affected [22].

As the actual living conditions of older men and women can be different, the personal experience brought on by fear of crime is much higher than the actual documented crime rates in an area [20]. In addition to experiencing crime first-hand, the coverage of crime through mass media adds to the fear of crime. Listening to and watching crime victims' share their painful experiences leads the viewer to also be vicariously emotionally traumatized [22]. The fear of crime is just one element of perceived risk in any given danger situation. Emotions of anxiety and insecurity will often proceed rising levels of fear and psychological pressure when an individual is exposed to a hazardous situation leading to impact on the well-being of older people. Although the communities of Taiwan are generally very safe and violent crime and muggings are very rare, older women should be cautious when walking on the street alone at night. This study suggests that older people evaluations of vulnerability or poor health are strong indicators of fear of crime for men and women. Future research is needed to investigate the influence of environmental surroundings upon the individual's fear of crime as well as the effect of environmental surroundings on the older community's fear of crime.

It is worthwhile to consider some of limitations of this research. First, although this sample has a good explanatory model; a larger sample could help to reveal small population effects. Another limitation of this study model is the absence of any demographic or other factors, such as education, social economic status, community location, experience, and so on. It is possible that a more heterogeneous sample taken from more divergent geographic locations in Taiwan will better represent the feelings of fear of crime in older people. This study used cross-sectional data from questionnaires at the community level (not the individual level) to gain an understanding of the social environmental dimension. Variable changes over time were not tracked and so are unknown. It is suggested that future research could have fixed samples for long-term tracking. In addition, although quantitative analysis can be taken in a short time period from a large amount of questionnaire data collection, this may not be enough to correctly measure complex human behavior. Supplementing this data with a series of interviews would help to better understand the true nature of this issue, and highlight the relevant factors related to each individual's fear of crime.

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International Journal of Management, Economics and Social Sciences
Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017)
2018, Vol. 7(S1), pp.40 – 57.
ISSN 2304 – 1366
http://www.ijmess.com

A Qualitative Study of Obesity Perceptions in Social Media through Twitter's Tweets

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This qualitative study applied Q methodology to explore general public's perception, attitude and behavior toward obesity and overweight using Twitter's tweets. A total of 76 statements extracted from Twitter status updates mentioning 'obesity' and 'overweight' were selected as the Q-statements. Twenty-one participants attended the sorting process and completed the Q sorts. Factor analysis was then applied on the Q sorts to extract meaningful factors. Three significant factors emerged from a factor analysis of the Q sorts, including obesity stigmatization, causes of obesity, and positive attitude and sentiment toward obesity. The results reveal pervasive negative stereotypes, alienations, and negative attitude toward overweight and obesity. The findings suggest that social media can actually reinforce body satisfaction perception, self-efficacy and stained health behavior. Most importantly, obesity prevention at the individual level should focus on an individual's behavioral change and at the society level requires careful and comprehensive presentation of the issue to the public.

Keywords: Obesity, Social media, Health promotion, Qualitative methods, twitter

Obesity is a medical condition in which excess body fat has accumulated to the extent that it may have negative impacts on an individual' s health, social, and financial outcomes (World Health Organization (WHO), 2016). In 2014, more than 1.9 billion adults aged 18 years and older in the world were overweight, among them over 600 million were obese (WHO, 2016). In addition, the WHO (2016) report indicates that 41 million of the world' s children population under the age of five were overweight or obese in 2014. Obesity is not only a problem for the developed countries; in fact, the number of children in the developing countries who are overweight or obese is 30% higher than in the developed countries. The rate of obesity has tripled in

Manuscript received May 20, 2017; revised September 23, 2017; accepted October 28, 2017.
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the developing countries over the past 20 years (Haidar and Cosman, 2011). In year 2010 alone, three to four million people died from obesity (Jacobs, 2014). Therefore, obesity and overweight are becoming serious issues for many countries today. Obesity and overweight are preventable health issues; the public, government and health provider should take serious action regarding this trend.

Cause and Consequence of Obesity and Overweight

Obesity is considered to be a multifactorial condition in which both environmental factors and genetic factors play a part. Leptin, also referred to as the obesity hormone, has been linked to obesity phenotype in humans (Galletta, 2016). The increase in obesity prevalence over the last decades has also been attributed to suboptimal macronutrient diet composition and insufficient physical activities (Tremblay and Lachance, 2017). Lack of physical activities and exercise will lead to obesity and overweight. Additionally, food advertising will influence food preference and eating behavior (Tarabashkina *et al.*, 2016; Neyens and Smits, 2016). Furthermore, sleeping habits and amount of sleeping time are also significant predictors of increased risk of adult obesity (Landhuis *et al.*, 2008).

Obesity is a complex chronic disease that has become a major public health problem in many countries throughout the world because of its high prevalence, causal relationship with many serious medical illnesses, adverse effects on quality-of-life, and marked economic consequences related to increased health care costs (Berthoud and Klein, 2017). A Health Survey from England in year 2013 indicated that people's Body Mass Index (BMI) over 30 will reduce about three years of lifetime whereas people over BMI 40 will reduce about eight to ten years of lifetime (National Health Service Choices, 2015). In addition, overweight children and teenagers have poorer self-image and lower self-esteem than normal weight. These situations will lead them to become cowardly and allow others to abuse them (Aparicio *et al.*, 2016). Social problems faced by overweight people are bullying and isolation during middle adolescence (Kaltiala-Heino *et al.*, 2016). Also, people who are depressed and anxious may be associated with obesity within individuals and families (Marmorstein and Iacono, 2016).

Social Media and Twitter Usage on Health Promotion and Education

Health promotion and education is the science and art of engaging people in actions that can help to optimize their health (O ' Donnell, 1989). Health promotion and education emphasizes physical,

psychological and society to generate ways that help people to avoid health issues such as obesity (Becker *et al.*, 2015). Social media has become an effective approach in increasing participation within the community and it is actively being used in promoting health-related matters. Social media interventions were effective in youth, older adults, low socioeconomic status, and rural area populations at risk for disadvantage which indicate that these interventions may be effective for promoting health equity (Welch *et al.*, 2016), sexual health promotion intervention (Gold *et al.*, 2012) and psychological disease monitoring (Reavley and Pikington, 2014). Social media is a platform that comprises online communication tools to support and facilitate social connections between users (Hansen *et al.*, 2010). Currently, over 2.1 billion online users have active social media accounts (Walters, 2016). The utilization and propagation of social media have grown up at the rate that other forms of media were unable to compare with. Popular social media platforms include Twitter, Facebook, Instagram, and YouTube.

Twitter was launched in the year 2006 which allows users to interact with other users by sending short messages called *Tweets*. On average, around 313 million monthly active users, 1 billion unique visits monthly to the site with embedded Tweets (Twitter, 2017). To make the tweets being connected to general topics, Twitter users can put hashtags together with a keyword to their post. By default, tweets from all the users are publicly available and searchable. According to Effing *et al.* (2011), Twitter has grabbed a lot of research attention. Twitter has been used to study antibiotics usage (Scanfeld *et al.*, 2010), to monitor depression and schizophrenia (Reavley and Pikington, 2014), and to evaluate cancer patient support (Sugawara *et al.*, 2012).

The supportive online communities and organizations provide compassionate, non-judgmental and anonymous platform for individuals to share experiences and opinions. The social media networking has been used to enhance communication and to increase accessibility and interactivity among social media users (Smith and Lambert, 2014). With rapid diffusion, low cost and broad availability, social media has become increasingly prominent in health information dissemination and health promotion. About 23% of social media users reported following a friend's personal health updates, 15% received health information from the Web, 11% posted health-related information, and 9% joined health-related groups (Fox, 2011).

Overall, willingness and capacity to engage with the mass media such as social media were seen as essential attributes of influential public health researchers (Chapman *et al.*, 2014). This study intended to explore the perception, attitude, and health behavior of the general public toward obesity and overweight issues by using Twitter as the platform. Understanding people' s opinions pertaining to the causes of and solutions for obesity can help health care practitioners, educators and government to design a more effective obesity prevention policy, and to improve the effectiveness of health education and promotion activities on social media.

METHODOLOGY

This study adopted a Q methodological approach to explore and describe people's perception, attitude and behavior toward obesity and overweight using Twitter updates or tweets. Typically, in a Q methodological study participants are presented with a sample of statements about some topics, called the Q sample. Respondents are then asked to rank-order (Q sorting) the statements from their individual point of view, mostly using a quasi-normal distribution. By Q sorting people give their subjective meaning to the statements, and by doing so reveal their subjective viewpoint or personal profile.

Q-methodology provides a scientific method for identifying perception structures that exist within certain individuals or groups (Yuen, 2005). According to Kim (1996), the focus of Q methodology is peoples' attitudes and perceptions that have been gained from personal experience. Q methodology is particularly suited for health-related inquiry concerned with the unconstrained expression of views (Dennis, 1986; Roger, 1991), especially in the study of attitude measurement within the field of health education and health promotion where subjective opinions are often sought, from laypersons and health professional to policymakers (Cross, 2005).

In this study, the procedure for performing Q methodological analysis comprises the following steps: (1) construct the Q sample; (2) select proper participants; (3) conduct Q sorting; and (4) perform data analysis.

-Q Sample

The Q sample consists of statements extracted from the Twitter updates pertaining to overweight or obesity. Q statements are self-referent statements made by a person in a social situation (Stephenson, 1953). To

collect the statements, first, a search was carried out on Twitter updates using keywords “Obesity”, “Obese” and “Overweight”. Data collection was performed in April 2015 on a daily basis. Upon completion, a total of 668 statements were in the concourse. After screening redundant and ambiguous statements, the number of statements reduced to 550. Next, experts familiar with Q methodology and obesity were invited to perform data categorization on the statements. Statements with the highest tweets and favorites in each category were selected for inclusion in the Q sample as they represent the current popular issues. Since the statements were grouped according to factors, it helps to overcome bias and preference in selecting statements (Paige and Morin, 2016). Generally, the number of Q-statements ranges from 20 to 100 (Dennis, 1986). The final structured Q sample contained 76 statements, covering the breadth and depth of the concourse. Lastly, selected statements were further edited for readability and clarity by the experts. The complete Q statements are presented in Appendix-IV.

-Selection of Participants

One of the most salient characteristics of Q-methodology is the use of a small sample, which is possible because intra-individual difference rather than inter-individual difference are considered significant (Yuen, 2005). Young adults are selected due to the rising number of these individuals participating in social media (Pew Research Center, 2015; Baumgartner and Morris, 2010).

A total of 21 participants were interviewed in this study. All participants are social media users. Aspects covered in the demographic profile include age, gender, race, education level, occupation, and Twitter account status. The majority of participants are aged between 21 to 30 years old (71.4%). More than half of all participants are female (61.9%) and Chinese (80.9%). In terms of education, about half of the participants hold a diploma or a college degree (52.4%). Meanwhile, about 42.9% of the participants are working adult, followed by students (38.1%). Lastly, only 3 of the 21 (14.3%) participants are frequent Twitter users.

The interviews were conducted between 1 June 2015 and 18 June 2015 in Malaysia. 7 respondents were interviewed through Skype and 14 respondents completed the Q-sorting through e-mail and mobile messaging Apps. All respondents completed the sorting process within 90 minutes to 2 hours. Before the

interview, participants received the information of Q-sample, Q-sort diagram and instructions of interview detail. The instruction and guideline provide three language settings, including English, Chinese, and Malay.

-Q Sorting

Q sorting involves the opinions or perceptions of the participants on an issue or matter. In the initial sort, participants were asked to categorize all the 76 statements into agree, disagree, and neutral. In the second sort, the 76 statements were sorted relative to one another on the Q-sort table. The Q-sort table is a quasi-normal distribution with a fixed number of statements placed under each scale point as shown in Table 1. The rating scale at the top row of the Q-sort table ranges from -5 to +5. The participants must adhere to the number of statements provided in the Q-sort table. The use of forced-choice is to allow participants to compare each statement with one another and use their personal viewpoints to place statements on the Q-sort table as they see fit. In such case, statements are examined in a relative sense instead of isolation. Finally, the resultant Q sort would be a matrix representing the participant' s operant subjectivity on the issue under consideration.

	Most disagree					**Neutral**			**Most agree**		
Scale	-5	-4	-3	-2	-1	0	1	2	3	4	5
Number of statements (Total = 76)	3	5	7	8	9	12	9	8	7	5	3

Table 1. Distribution of Q Samples

-Data Analysis

The analysis of the Q sorts includes calculation of the correlation matrix of all Q sorts, performing factor analysis to identify the number of significant factors among the Q sorts, computation of factor scores (Z-scores), and ranking of factors. PQMethod 2.35 was used to carry out the above analysis. Principle component factor analysis in PQMethod yields the eigenvalues of the Q factors. Factors with eigenvalues more than 1.00 are extracted. Those with less than this amount are regarded as insignificant and generally of too little interest to warrant further investigation. The interpretation of Q factors and Z-scores focused on

specific statements that were defined as distinguishing statements. A distinguishing statement is when a statement's score on two factors is higher than the difference scores (McKeown and Thomas, 2013).

RESULTS

Analysis of the Q-sort data provided by the 21 participants revealed distinct attitude, perception, and behavior toward obesity among participants. Three significant factors related to obesity issue were identified. As shown in Table 2, the three factors, expressed as Factor I, II, and III respectively, explained 52% of the total variance and their composite reliabilities range from 0.889 to 0.923. Correlations between the factors are all less than 0.5, ranging from -0.034 to 0.350, indicating that the factors are more distinct than alike. In addition, the salient statements that are used to interpret the three factors can be identified through factor scores. The followings discuss the characteristic statements associated with the three factors. For ease of interpretation, this study has followed common Q methodological practice to provide each factor with a theme.

	Factor I	**Factor II**	**Factor III**
Composite Reliability	0.889	0.923	0.889
Eigenvalues	6.354	1.226	1.010
% Explanation Variance	25	15	12
Correlation analysis			
Factor 1	1.000		
Factor 2	0.350	1.000	
Factor 3	-0.034	0.095	1.000

Table 2. Factor Summary

Factor I: Obesity Stigmatization on Twitter

There were ten (47.6%) participants classified as factor I. The statements associated with Factor I that participants most positively agreed and disagreed with are listed in Table 3 (see Appendix-I). Apparently, participants in factor I agree that overweight is unhealthy (item 23) and that obesity is harmful and might cause mental and physical issues (items 27 and 36). Besides, factor I participants feel annoyed towards obese people who feel comfortable with obesity (item 20) and they believe "plus-size models" should not be publicized (items 32 and 6). At the same time, participants within this factor highly disagree that looking

healthy means looking fat and looking normal means looking obese (item 7). In contrast, they believe obese people should make a change towards a more healthy body figure (item 15). Consequently, factor I identifies pervasive negative stereotypes, alienations, and negative attitude toward overweight and obese people.

Factor II: Causes of Obesity

A total of seven (33.3%) participants loaded significantly on factor II. As shown in Table 4 (see Appendix-II), participants in factor II strongly agree that bad diet leads to overweight or obesity rather than lack of exercise (item 63) and disagree that obesity is a rich people problem (item 54). Participants in this factor also think that obesity can also be caused by higher level of stress (item 48) and eating disorders (item 70). As a number of statements regarding causes are being highlighted in factor II, thus, factor II is characterized by the causes of obesity.

Overall, participants in factor II agree that maintaining a healthy diet is a personal business (item 23) instead of attributing the cause to the commercial activities of the fast food companies (item 29). In addition, a consensus among these participants is that calling obesity a disease (item 1) or attacking overweight people (items 43 and 37) will not help obese people to lose weights and make healthy choices.

Factor III: Positive Attitude and Sentiment toward Obesity

There were four (19.0%) participants classified as factor III. Refer to Table 5 (see Appendix-III) for the statements with which they most agreed and disagreed. Factor III reveals discourse of encouragement and acceptance for individuals with overweight and obesity issue. The “love your body” movement is being accepted and favored by the factor III participants but they stress that the people who are extremely underweight or overweight should not be glorified (item 51). In the meantime, they highly disagree that being obese is as dangerous as being anorexic and believe that one of these serious issues is not protected via “anti-shaming” and “body positivity” (item 4). Besides, these participants are totally against fat shaming but are aware that it is not great to be obese or overweight (item 35). Meanwhile, the participants feel very motivated when seeing an overweight person is working hard in the gym (item 53). Overall, the participants in factor III have a more positive attitude and sentiment toward obesity.

DISCUSSION

This study applied a qualitative approach to explore general public's perception, attitude, and health behavior toward obesity and overweight using Twitter's tweets and Q methodology. Three factors exemplify people's subjective opinions on obesity issues were identified, namely obesity stigmatization, causes of obesity, and positive attitude and sentiment toward obesity.

The obesity stigmatization factor reveals that there is a common perception of obesity being unhealthy or even obese people are not beautiful. Observation on tweets related to overweight and obesity shows negative sentiment usually extends to verbal aggression and insults. According to Park (2015), the Tweets on Twitter negativity had a significant effect on anger and disgust. This factor is supported by the study of (Brewis *et al.*, 2011) who reported that a rapid globalization of fat stigma where obese people are increasingly viewed as ugly, undesirable, lazy, or lacking in self-control. Obesity or weight stigma may trigger unhealthy dietary behavior and cause psychological issues such as body dissatisfaction, low self-esteem, or the pursuit of thinness (Pearl *et al.*, 2015). According to Pearl *et al.* (2015), for individuals who had previously experienced weight stigma, media exposure can trigger the intentions and self-reported behavior shortly and at the same time may contribute to worse psychological functioning and physical activity. The result signifies that shaping people's health behavior should start with reducing obesity stigmatization.

Participants who ascribed to factor II are largely concerned about the potential causes of obesity. Participants in this factor believe that the major causes of obesity are due to unbalance and unhealthy diet and health condition instead of lack of physical activities, and that maintaining a healthy diet is essentially a personal issue. According to Foster-Schubert *et al.* (2012), lifestyle-change program, incorporating either combined or separate dietary weight loss or moderate exercise intervention produced significant reductions in body weight. However, Carroll (2015) mentioned that physical activities might not be the key determinant of unhealthy weight in children. Although it is generally true that bad diet and overeating are the major factors of obesity, recent literature has revealed that other environmental factors such as media and food advertising also contribute to positive energy balance that underlies body-weight gain and should be considered in order to tackle obesity (Tremblay and Lachance, 2017). In addition, it seems that genetic inheritance is another important factor that has been overlooked. The results show that most people do not fully understand the causes and consequence of obesity. The public nowadays gravitates toward social

media for health information and treatments. Disseminating accurate information regarding overweight and obesity can actually help people to take the proper action to tackle the problem.

The third factor, positive attitude and sentiment towards obesity, demonstrates a more positive look at obesity. This finding is congruent with the U.S. government health survey conducted from 1988 through 2014 which shown that socially accepted normal body weight is shifting toward heavier weight (USA Today, 2017). The positive portrayals and information can significantly influence public attitudes on obesity. According to our research finding, a supportive environment can enhance health and lower health disparities. Both factors I and III are pertaining to attitude yet these two factors differ in the ways of perceiving obesity. Nevertheless, both factors recognize that being obese is unhealthy.

It is interesting to note that obesity prevention and the related behavior change did not emerge as significant factors. Most of the collected tweets did not mention weight-related behavior change or obesity prevention and consequence (see Appendix-IV). This indicates that most people might not have enough knowledge regarding obesity prevention and the potential detrimental effects of obesity. Previous research also found that social media interventions to promote healthy diet and exercise did not associate significantly with differences in weight loss or physical activity (Williams *et al*., 2014). It should note that factors I and III merely recognize obesity is a problem or unhealthy, but more specific negative impacts of obesity have not been identified. Sun *et al*. (2016) recommend raising awareness of obesity as a societal issue and mobilizing collective efforts. In brief, messages regarding behavior change towards a healthier lifestyle, prevention and detrimental effects of obesity are not gaining great attention on social media which make these factors insignificant.

CONCLUSION

This study identified three different perceptions of obesity by the general public: obesity stigmatization, causes of obesity, and positive attitude and sentiment toward obesity. The findings of this study provide several implications for health care practitioners and health promotion researchers. First, the obesity stigmatization or negative sentiment that dominates the conversations related to obesity should be prevented since lower self-esteem of obese people will only worsen the obesity epidemic. Health promotion and

education campaigns could increase participation within the community to provide positive messages or stories, especially from influential individuals, about obesity on social media in order to educate the people who have possessed such a negative attitude. It is known that tweets which gain plenty of attention are attributed to public figures and celebrities instead of the attractiveness of the content. With the spreading of positive messages on social media, there is a greater chance for the public to understand the effect of social media discourse on obesity and even take actions such as practicing healthy lifestyles.

Second, anonymity allows Twitter users to feel more comfortable sharing sensitive information and personal opinions. Social media such as Twitter has the opportunity to overcome the culture, language, location, social class, and other obstacles to interpersonal communication on obesity issues. Health care providers and policymakers can consider the impact of health care intervention and education that can be performed via open public social media or via private networks, based on the different information and knowledge to deliver the proper messages to the public. Third, the study showed that only dietary habit and health condition are the factors that the public most aware of. As a consequence, health promotion programs should emphasize the causes of obesity which have been overlooked on social media. Lastly, the results indicated that behavior change and the effects and prevention of obesity issues are not well addressed by social media users. Therefore, health care providers should emphasize more about the seriousness of getting obesity, the ways to prevent becoming obese, as well as the benefits to get rid of obesity.

This research demonstrates a different approach from other past studies which is to implement a qualitative approach to investigate the people's opinions toward obesity. The Q methodology and PQMethod address a key issue facing obesity prevention, public attitude and perception about the issue as expressed on the Twitter channel. Hence, this research can be useful for health promotion researchers who have not benefited from a qualitative inquiry. The present study collected opinions of public on obesity issues via Twitter's tweets. It is not possible at the moment to systematically expose all Twitter users. Consider the heterogeneity of social media users may make understanding of the benefit of social media challenging. For further study, extending the observation period can enhance a better understand of social opinions regarding obesity.

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Appendix-I

Item No.	Statement	Z -Score
23	Being overweight is unhealthy and it is your personal responsibility to do your best to become fit. Please do.	2.041
18	I mean we complain about the obesity rate but yet it's $1 for a double cheeseburger and $10 for a small portion of a healthy meal.	1.897
36	For now I think it's enough to just remind you that most severely obese people are struggling with mental issues as well as physical ones.	1.825
27	Fat is harmful and obesity should not be a badge of pride.	1.705
32	Being overweight is not healthy so I do not understand why people are arguing that 'plus size models' should be in the public eye.	1.561
6	Plus Size Appreciation is not promoting obesity. It's making people who are constantly put down feel good about themselves.	1.489
20	Obese people who glamorize their weight annoy me because it is unhealthy and when you are having a heart attack, you would not be loving your curves.	1.489
15	Make-up can't hide my obesity. Only starvation can remove my fat. I don't want to be looking at obesity in the mirror forever. I must change.	1.417
54	Obesity is a rich people problem.	-1.369
21	Lack of sleep is putting children at risk of overweight and obesity.	-1.417
49	A salon owner claims that obese staff ruined her business by sneaking out for takeaways.	-1.561
25	If I was getting overweight or obese, and my friends were telling me "Rock it girl", "love yourself". I would get away from these friends.	-1.561
2	Study identifies childhood obesity as a risk factor for dropping out of school.	-1.633
7	You look healthy = You look fat; You're too skinny = You're doing it right; You look normal = You are obese.	-1.753
57	The government were saying that, they might implement an obesity tax, as a scheme to battle obesity.	-1.969
11	You see fat families? When the mum is obese. The dad is obese. And so are the kids? Sickening. They should be banned from public.	-2.041

Table 3. Descending Z-Scores of Salient Statements Associated with Factor I

Appendix-II

Item No.	Statement	Z -Score
1	Calling obesity a disease causes obese people to be less motivated to lose weight and make healthy choices, according to a study.	1.930
23	Being overweight is unhealthy and it is your personal responsibility to do your best to become fit. Please do.	1.915
63	Obesity due to bad diet not lack of exercise.	1.770
43	No respect for people attacking overweight people at the gym who are trying to turn their life around.	1.717
48	Reduced stress level can help obese people to lose weight.	1.485
70	Eating disorders are not just extremely thin people. They can be overweight morbidly obese or a normal weight person.	1.269
75	I hate when I go shopping and I can't find sizes for overweight people, it's so difficult to find and when you find something it's horrible.	1.163
29	McDonald's targets children to ensure that future generations grow up obese and lethargic.	-1.414
76	Watching too much television can cause kids to be overweight and obese.	-1.487
19	If you make fun an overweight person working out at the gym I'll key your vehicle.	-1.574
2	Study identifies childhood obesity as a risk factor for dropping out of school.	-1.860
25	If I was getting overweight or obese, and my friends were telling me “Rock it girl”, “love yourself”. I would get away from these friends.	-2.002
54	Obesity is a rich people problem.	-2.037
37	Every time my dad sees an overweight person & says "Look at that fat fuxx." saves me from letting my weight get out of control.	-2.056
11	You see fat families? When the mum is obese. The dad is obese. And so are the kids? Sickening. They should be banned from public.	-2.342

Table 4. Descending Z-Scores of Salient Statements Associated with Factor II

Appendix-III

Item No.	Statement	Z –Score
23	Being overweight is unhealthy and it is your personal responsibility to do your best to become fit. Please do.	1.805
51	I love this whole love your body movement, but if you are extremely under/overweight, it shouldn't be glorified. Like you're killing yourself.	1.805
67	Obesity is becoming a real problem in the United Kingdom.	1.690
10	When more people are dying from obesity than starvation, there is a big problem.	1.628
43	No respect for people attacking overweight people at the gym who are trying to turn their life around.	1.628
53	Seeing an overweight person working hard in the gym is very motivating for me.	1.628
35	I am totally against fat shaming, but do not tell people that it is great and okay to be obese or overweight.	1.513
50	One way to lose weight? Studies show obesity is lower in marijuana users than in non-users.	-1.452
4	Being obese is as dangerous as being anorexic. Yet one of these serious issues is protected via "anti-shaming" and "body positivity".	-1.513
24	People at a normal weight who believe they are fat have a much greater risk of becoming obese later in life.	-1.628
22	Obese people may have lower dementia risk.	-1.628
8	Several new studies add to a body of evidence that being overweight may have health benefits.	-1.628
15	Make-up can't hide my obesity. Only starvation can remove my fat. I don't want to be looking at obesity in the mirror forever. I must change.	-1.805
74	Overweight teen tries to defend himself: I have a slow metabolism. I'm a nervous eater. I’m related to Rubeus Hagrid (character in Harry Potter, who is a giant human).	-1.920
54	Obesity is a rich people problem.	-1.920

Table 5. Descending Z-Scores of Salient Statements Associated with Factor III

Appendix-IV

No.	Q Statement
1	Calling obesity a disease causes obese people to be less motivated to lose weight and make healthy choices, according to a study.
2	Study identifies childhood obesity as a risk factor for dropping out of school.
3	Both ancient Egyptian and Greek medicine recognized obesity as a medical disorder.
4	Being obese is as dangerous as being anorexic. Yet one of these serious issues is protected via "anti-shaming" and "body positivity".
5	Foods that are high in nickel are linked to obesity in some women.
6	Plus Size Appreciation is not promoting obesity. It's making people who are constantly put down feel good about themselves.
7	You look healthy = You look fat; You're too skinny = You're doing it right; You look normal = You are obese.
8	Several new studies add to a body of evidence that being overweight may have health benefits.
9	Obesity is more heritable than schizophrenia, high blood pressure, and alcoholism.
10	When more people are dying from obesity than starvation, there is a big problem.
11	You see fat families? When the mum is obese. The dad is obese. And so are the kids? Sickening. They should be banned from public.
12	An anti-obesity law has passed in Japan. It's now illegal to be overweight or fat in Japan.
13	Training leg is painful especially when you are an overweight baby boomer. But I am going to do this.
14	Wealthier men have a higher rate of obesity than poor. Poor women have higher rate of obesity than wealthier women.
15	Make-up can't hide my obesity. Only starvation can remove my fat. I don't want to be looking at obesity in the mirror forever. I must change.
16	Overweight type-2 diabetes patients outlive thinner ones, study says.
17	Teenagers who misperceive their weight as overweight are actually more likely to overeat compared to teenagers who accurately perceive their weight.
18	I mean we complain about the obesity rate but yet it's $1 for a double cheeseburger and $10 for a small portion of a healthy meal.
19	If you make fun an overweight person working out at the gym I'll key your vehicle.
20	Obese people who glamorize their weight annoy me because it is unhealthy and when you are having a heart attack, you would not be loving your curves.
21	Lack of sleep is putting children at risk of overweight and obesity.
22	Obese people may have lower dementia risk.
23	Being overweight is unhealthy and it is your personal responsibility to do your best to become fit. Please do.
24	People at a normal weight who believe they are fat have a much greater risk of becoming obese later in life.
25	If I was getting overweight or obese, and my friends were telling me "Rock it girl", "love yourself". I would get away from these friends.
26	Eating micronutrient or fiber-rich bar two times per day increase metabolism and decrease inflammation in obese people without diet change.
27	Fat is harmful and obesity should not be a badge of pride.
28	I'm apparently overweight but I look good? Strange.

No.	Q Statement
29	McDonald's targets children to ensure that future generations grow up obese and lethargic.
30	I can say this because I was obese. I've been there and made all the excuses! Stop mollycoddling people & promote healthy lifestyle change!
31	Dr. Allen Litcher: "Obesity will likely surpass smoking as the leading preventable cause of cancer."
32	Being overweight is not healthy so I do not understand why people are arguing that 'plus size models' should be in the public eye.
33	Stop promoting being morbidly obese as beautiful. You wouldn't do it with anorexia, it's not beautiful. It's a death sentence.
34	Hyperinsulinemia drives diet-induced obesity independently of brain insulin production.
35	I am totally against fat shaming, but do not tell people that it is great and okay to be obese or overweight.
36	For now I think it's enough to just remind you that most severely obese people are struggling with mental issues as well as physical ones.
37	Every time my dad sees an overweight person & says "Look at that fat fuxx." saves me from letting my weight get out of control.

38	I despise parents who say that it is not their fault that their child is overweight.
39	Studies suggest standing more could lower risk for obesity, illness, and death.
40	15 minutes of laughter everyday can help reduce your risk of obesity and boost your metabolism.
41	4 out of 5 firefighters in US are overweight or obese, and about half of firefighters killed in the line of duty suffer heart attacks.
42	Important reminder: not every overweight person dislikes their body and wants it to change!!! Do not project societal standards on us!!!
43	No respect for people attacking overweight people at the gym who are trying to turn their life around.
44	I was once obese. Trust me, you're lying to yourself if you have the 'as long as I'm happy' mentality to justify your condition.
45	I'm: So stressed. So depressed. So obese. So exhausted. So fat. So ugly. So worthless. So unwanted. So disappointing. So disgusting.
46	1-4 children in America are obese, but please keep telling me how bad cutting weight is for my body.
47	I'm sorry but the people who embrace obesity only do so because they're too lazy to fix it.
48	Reduced stress level can help obese people to lose weight.
49	A salon owner claims that obese staff ruined her business by sneaking out for takeaways.
50	One way to lose weight? Studies show obesity is lower in marijuana users than in non-users.
51	I love this whole love your body movement, but if you are extremely under/overweight, it shouldn't be glorified. Like you're killing yourself.
52	Pizza Hut offers free pizza to everyone called Charlotte this weekend, as a token of their devotion to childhood obesity.
53	Seeing an overweight person working hard in the gym is very motivating for me.
54	Obesity is a rich people problem.
55	Standing desks are coming to schools, to cure obesity and increase attention spans.
56	Physical inactivity is a bigger risk factor for early death than "Smokadiabesity" (smoking, diabetes and obesity together).

No.	Q Statement
57	The government were saying that, they might implement an obesity tax, as a scheme to battle obesity.
58	A new study shows many overweight people have a distorted self-image. They tell themselves, I'm not fat. I'm just easy to see.
59	Everyone is getting skinny and I am getting obese.
60	Parents rarely spot child obesity.
61	I am overweight and this is nothing but facts. We should not promote unhealthy lifestyles.
62	I used to tell myself I'm naturally overweight, I'm naturally big boned. But there are no fat people. Take Action!
63	Obesity due to bad diet not lack of exercise.
64	You think I haven't tried to lose weight? Ask most overweight women and they have tried it is not as black and white as you may think.
65	Overweight prevalence of pre-school children in ASEAN. It is alarming!!!
66	I've met a few people who say they don't like the taste of water. They were all obese. I assume it's correlated.
67	Obesity is becoming a real problem in the United Kingdom.
68	I was overweight but when I started doing gymnastics, I lost weight and I am not that skinny but confident.
69	Obesity is a frequently overlooked factor that can contribute to an increased cancer risk.
70	Eating disorders are not just extremely thin people. They can be overweight morbidly obese or a normal weight person.
71.	Being the highest percentage of obese people in South East Asia is not helping in our progress for a better Malaysia. Pondering times.
72.	For each hour of sleep lost, the odds of an adolescent being obese rise by 80%.
73	I admire an overweight person in the gym trying to get right. I was once there, my friends.
74	Overweight teen tries to defend himself: I have a slow metabolism. I'm a nervous eater. I'm related to Rubeus Hagrid (character in Harry Potter, who is a giant human).
75	I hate when I go shopping and I can't find sizes for overweight people, it's so difficult to find and when you find something it's horrible.
76	Watching too much television can cause kids to be overweight and obese.

International Journal of Management, Economics and Social Sciences
Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017)
2018, Vol. 7(S1), pp.58 – 72.
ISSN 2304 – 1366
http://www.ijmess.com

Efficiency Evaluation of China's Investment in Africa under the Background of Constructing 'Silk Road Economic Belt': Application of DEA Model and Malmquist Index Method

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In recent years, with implementation and propulsion of the strategic planning "One Belt and One Road" of China, quality and efficiency of China's foreign direct investment have increasingly become a focused issue. This paper utilizes the DEA model and Malmquist index method to select the data of China's investment in 20 countries of Africa and conducts the empirical research on dynamic evaluation of efficiency of China's direct investment in Africa. The result shows that the general efficiency of China's direct investment in Africa is in a declined fluctuation trend, while the technical efficiency of the investment is in a constant rising trend, and direct investment in most host countries has reached or is reaching the optimal scale. From the perspective of country difference, the efficiency of direct investment in a small number of host countries has been improved while that in most host countries has declined. With improvement of African countries in absorbing and utilizing foreign technologies and management level and effective innovation of China's direct investment in host countries, the efficiency of direct investment in host countries will be constantly improved. The suggestions such as optimizing investment location selection, emphasizing on the linkage between support facilities and industrial chain of the investment project, improving technology spillover efficiency and enhancing infrastructure investment are proposed.

Keywords: Africa, foreign direct investment, efficiency evaluation, DEA, Malmquist index, Silk Road Economic Belt

Africa is the strategic intersection in the planning and construction of " one Belt and One Road" . As a continent with the largest number of developing countries, Africa possesses abundant natural resources, labor resources and giant market potential. China is the largest development country and the second largest economic entity in the world, thus the complementarity between Chinese economy and African economy is good. Both sides possess many common integrating points in economic strategic interests. Economic and

Manuscript received May 20, 2017; revised September 17, 2017; accepted October 28, 2017.
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trade cooperation between China and Africa can not only promote industrialization and modernization of Africa, but also has significant impact on economic development of China and the world. Since 2000 when " China-Africa Cooperation Forum" was successfully started, Sino-African trade and investment have entered into a constantly rapid development period. On December 5, 2015, China-Africa Cooperation Forum - Johannesburg Summit was successfully held. This summit upgraded the Sino-African relationship into the comprehensive strategic partnership and approved Summit Declaration and Action Plan (2016-2018). Taking the opportunity of Johannesburg Summit, both parties will comprehensively promote Sino-African cooperation, industrialization and agricultural modernization of Africa and accelerate effective connection between African dream and the Chinese dream. Africa is the strategic highland of " 21st Century Maritime Silk Road", thus African countries will positively participate in the planning and construction of " One Belt and One Road" so as to improve the connectivity level of Africa. Sino-African cooperation and development will usher a great historical opportunity.

In recent years, China's direct investment in Africa is increasing rapidly, which has greatly promoted Sino-African trade development and accelerated excessive capacity transfer and industrial upgrading of China. From 2008 to 2014, the annual average growth rate of stock of China's direct investment in Africa was about 27% and the investment had reached USD 32.35 billion (by the end of 2014). China's direct investment in Africa has covered 52 countries, and the investment coverage rate exceeds 90%. The investment range is no longer limited to the field of resources and minerals such as petroleum, but has been expanded to the fields such as construction industry, financial industry, manufacturing industry and agriculture. At the time when large-scale increase of China's direct investment in Africa is achieved, the problems such as frequent investment risks, extensive operation and industrial disperse also appeared. Quality and efficiency of the investment in Africa also aroused people's attention. For this reason, it is quite necessary to carry out the research on efficiency evaluation of China's direct investment in Africa.

LITERATURE REVIEW

Research of domestic and foreign scholars on economic growth effect of host countries by absorbing and

utilizing foreign investment. Haskel and Slaughter [1] studied the economic growth effect caused by foreign companies on the host countries respectively by taking Venezuela and England as examples. The result considers that technology spillover effect of foreign investment shows positive correlation. Dupasquier and Osakwe [2] studied the effect of utilizing foreign investment in African countries. The result indicates that the promotion effect of foreign investment is quite obvious. Chunying and Bo [3] utilizes VAR model to study the influence of foreign direct investment absorbed by China on the economic growth of China and the balanced and dynamic relations of influencing factors. The result shows that foreign investment has positive effect on economic growth. Shujie and Genfu [4] verified that foreign investment could promote improvement of production technology efficiency of host countries and pointed out that attracting foreign investment was an important manner for emerging industrial countries in pursuing the developed countries. Research of Hong and Shumie [5] indicates that foreign investment has positive effect on China's economic growth and has obviously promoted employment and economic growth of China which is in a fluctuation trend. Meibo and Dongyan [6] considers that China's investment in African infrastructure construction is beneficial for propelling capacity building of Africa and improving its self-development capacity. Based on the research on evaluation of China's investment in African agriculture, Shaosa [7] considers that China's investment in African agriculture can help solve the food crisis which bothers Africa for a long term.

Researches of domestic and foreign scholars on efficiency evaluation of direct investment in host countries. Most researches are about investment efficiency evaluation carried out mainly by DEA and relevant models. Kravisova [8] utilizes DEA model to evaluate the efficiency of foreign direct investment in host countries. The result shows that the influence of foreign investment on economy of host countries is positive. Badunenko, Henderson and Houssa [9] utilizes DEA method to conduct empirical analysis on the data from 35 countries in Africa. The research considers that human resources and material resources are principal factors in economic growth of Africa. Favorable government management and infrastructure are also beneficial for economic development of Africa. Based on DEA model, Yuechun and Yingzi [10] evaluated the foreign investment efficiency and influencing factors of China's environmental protection industry by taking the panel data of more than 30 provinces and cities nationwide from 2003 to 2009 as samples and proposed relevant suggestions for promoting foreign investment efficiency. Ming'e [11] utilizes

DEA method to construct an environmental technology model and utilizes SBM directional distance function and common boundary ML productivity index to measure the inter-provincial environmental efficiency of China between 1992 and 2012, dynamic evolution and trend of environmental TFP. Bo [12] utilizes DEA method to evaluate the promotion effect of China's direct investment in Africa on economic growth of host countries and suggests that the general development trend of China's investment in Africa shall expand the scale and control the investment in part of the host countries.

In conclusion, existing literatures about evaluation methods, models and empirical researches of foreign direct investment efficiency and research on economic growth effect of host countries by absorbing and utilizing foreign investment have certain reference meaning. However, the researches on efficiency evaluation of China's direct investment in Africa are relatively less. Based on this, this paper utilizes the DEA model and Malmquist index method to select the data from 2008 to 2014, conducts the research on efficiency evaluation of China's direct investment in African host countries from the perspective of the host countries and proposes specific policies and suggestions.

Model Description

-DEA Model

Data envelopment analysis (DEA) is used for evaluating the investment efficiency. It is an efficiency evaluation method developed based on the concept of relative efficiency by determining the production leading surface from the perspective of total factor input. It is for evaluating and sorting the relative efficiency of each decision-making unit of the same type. DEA method does not need to pre-estimate the parameters or assume the weight or make the data being dimensionless, thus it has certain superiority in avoiding subjective factors, simplifying algorithm and reducing errors than other evaluation methods [13].

-Malmquist Index of Productivity and its Decomposition

Malmquist index of productivity was proposed by Malmquist, a Sweden economist, in 1953. Based on DEA, Fare etc. converted the Malmquist index of productivity from theoretical index into empirical evaluation index

and constructed the Malmquist index of productivity $M(x^{t+1}, y^{t+1}, x^t, y^t)$ from t th period to t+1th period as shown in formula (1). In the formula, $D^t(x^{t+1}, y^{t+1})$、$D^t(x^t, y^t)$ respectively refer to the distance function of the evaluation object in the t-th period and t+1th period based on technical reference of the t-th period.

$$\mathrm{M}(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \right]^{1/2}$$

Fare further decomposes the Malmquist variability index of productivity ($tfpch$), into technical efficiency change ($effch$) and technical change ($techch$). Wherein the technical efficiency change ($effch$) is further decomposed into pure technical efficiency change ($pech$) and scale efficiency change ($sech$).

Therefore, formula (1) can be decomposed into formula (2) [14]:

$$\begin{aligned} & M(x^{t+1}, y^{t+1}, x^t, y^t) \\ &= \frac{D^{t+1}(x^{t+1}, y^{t+1} \mid VRS)}{D^t(x^t, y^t \mid VRS)} \cdot \frac{D^{t+1}(x^{t+1}, y^{t+1} \mid CRS)}{D^{t+1}(x^{t+1}, y^{t+1} \mid VRS)} \cdot \frac{D^t(x^t, y^t \mid VRS)}{D^t(x^t, y^t \mid VRS)} \cdot \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \right]^{1/2} \\ &= effch \times techch \\ &= pech \times sech \times techch \\ &= tfpch \end{aligned}$$

The relations between $tfpch$, $effch$, $techch$, $pech$ and $sech$ can be obtained according to the decomposition of formula (2), as shown in Figure 1. From t-th period to t+1th period, $tfpch$ refers to change of production efficiency, $tfpch > 1$ refers to improvement of productivity level and on the contrary otherwise; refers to displacement degree of production leading edge which can reflect the change conditions and is also referred to as "leading surface movement effect"; $techch > 1$ refers to technical frontier progress and on the contrary otherwise; $effch$ can reflect technical efficiency changes of the evaluation object, thus it is also referred to as "catching-up effect". $effch > 1$ refers to relative improvement of the evaluation object in technical efficiency and on the contrary otherwise; $pech$ and $sech$ decomposed from $effch$ respectively reflect the change conditions of pure technical efficiency and scale efficiency of the evaluation object, $pech > 1$ refers to efficiency promotion of the evaluation object by improving technology and management and on the contrary otherwise; $sech > 1$ refers that the evaluation object is approaching the optimal scale and on the contrary otherwise. This paper will calculate the Malmquist index of productivity of China's investment in each host country in Africa and each decomposed index analyzes the dynamic efficiency change of

China's direct investment in each host country and proposes suggestions for strategy adjustment and efficiency improvement of China's investment in the host countries in Africa.

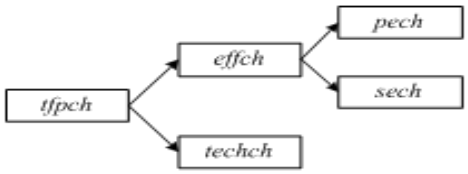

Figure 1. Decomposition of $tfpch$

Evaluation Index and Evaluation Object

-Evaluation Index and Data Source

It is normally considered that effects of foreign direct investment are mainly shown in promoting economic growth, trade development, tax revenue, financial income growth and infrastructure construction of the host countries. This paper takes the stock of China's direct investment in Africa, population in economic activities and labor market efficiency index of the host country as the input factors and takes GDP of the host country, per capita GDP of the host country, export volume of the host country, fiscal revenue of the host country and infrastructure development index of the host country as the output factors. The input factors are expressed by X_1 and X_2, and the output factors are expressed by $Y_1 \sim Y_5$ as shown in Table 1.

-Evaluation Object

To ensure accuracy of the result in utilizing DEA to conduct efficiency evaluation, the evaluation objects in the evaluation process need to be provided with similar characteristics. To ensure that the evaluation result has a reasonable distinction degree, the number of evaluation objects shall not be less than twice of the product multiplying the number of input indexes by the number of output indexes [15]. This paper selects top 20 host countries in the ranking of stock of China's direct investment in Africa by the end of 2014 as the evaluation objects. They are respectively: South Africa, Algeria, Nigeria, Zambia, Congo (Kinshasa), Sudan, Zimbabwe, Angola, Ghana, Congo (Brazzaville), Namibia, Ethiopia, Tanzania, Kenya, Egypt, Mozambique, Mauritius, Uganda, Guinea and Chad. Stock of China's direct investment in the 20 host countries accounts for 88.67% of the total stock of China's direct investment in the entire Africa (as shown in Figure 2). The

number of evaluation objects is twice of the product multiplying the number of input indexes by the number of the output indexes so as to satisfy the requirements for evaluation objects.

Index Type	Name of Index	S/N	Data Source
Input Index	Stock of China's Direct Investment in the Host Country	X_1	*Statistical Bulletin of China's Outward Foreign Direct Investment*
	Population in Economic Activities of the Host Country	X_2	*African Statistical Yearbook*
	Labor Market Efficiency Index of the Host Country	X_3	*Global Competitiveness Report*
Output Index	GDP of the Host Country	Y_1	World Bank Database
	Per Capita GDP of the Host Country	Y_2	World Bank Database
	Export Volume of the Host Country	Y_3	Database of UNCTAD
	Fiscal Revenue of the Host Country	Y_4	Calculated according to relevant data in *African Statistical Yearbook*
	Infrastructure Development Index of the Host Country	Y_5	*Global Competitiveness Report*

Source: Data of China's direct investment in African countries come from Statistical Bulletin of China's Outward Foreign Direct Investment, population in economic activities, GDP, per capita GDP and export volume of each host country in Africa come from African Statistical Yearbook, world bank database and database of UNCTAD, labor market efficiency index and infrastructure development index of the host country comes from Global Competitiveness Report and fiscal revenue of the host country is calculated according to the data in African Statistical Yearbook (please refer to Table 1).

Table 1. Input Index and Output Index

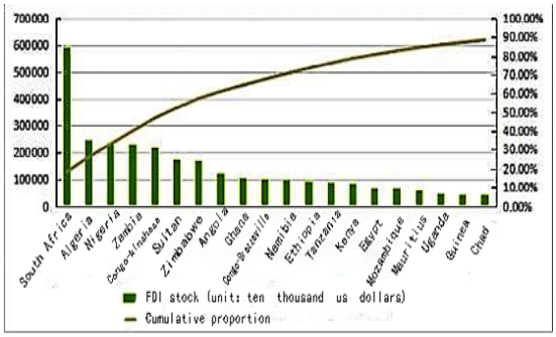

Figure 2. Stock of China's Investment in Top 20 Countries of Africa and Pareto Diagram (up to the end of 2014)

Evaluation Result and Analysis of China's Direct Investment in African Countries

-Analysis on Overall Efficiency

The overall efficiency of China's direct investment in 20 countries of Africa from 2008 to 2014 is calculated by the Malmquist model and DEA P 2.1, and the evaluation result is as shown in (Table 2). The efficiency tendency chart (as shown in Figure 3) for China's direct investment in host countries of Africa is drawn. Analysis on the evaluation result is as follows:

From the perspective of overall efficiency change ($tfpch$): the overall efficiency of China' s direct investment in host countries of Africa from 2008 to 2014 is in a downtrend, and the average value of $tfpch$is only 0.803. However, the investment efficiency from 2013 to 2014 is in a rapid rising trend. It indicates that the overall efficiency of China' s direct investment in Africa is in a declined fluctuation trend, but it is turned to a rising trend in recent years.

From the perspective of technical efficiency change ($effch$): technical efficiency of China's direct investment in host countries of Africa from 2008 to 2014 is in a stable trend, and the average value of $effch$ is 1.047. Wherein the technical efficiency from 2010 to 2011 slightly declines, but on the whole, the technical efficiency of China's direct investment in Africa is generally maintained stable.

From the perspective of pure technical efficiency index ($pech$): pure technical efficiency of China's direct investment in Africa from 2008 to 2014 is in a stably rising trend and the average value of $pech$ is 1.047, wherein the efficiency was greatly improved from 2010 to 2013, which was increased by 20.4%. However, the technical and management level of 20 countries of Africa in absorbing China's investment from 2008 to 2014 was generally maintained stable.

From the perspective of scale efficiency ($sech$): scale efficiency of China's direct investment in host countries of Africa from 2008 to 2014 is stable and the average value of $sech$ is 1.000. The scale of China' s direct investment in 20 countries of Africa has generally reached or is close to the optimal scale.

Technical change ($techch$) reflects the advance and retreat change of technical leading surface. Advance of technical leading surface indicates that China's direct investment has obtained effective innovation activities and on the contrary otherwise. The result shows that the technical leading surface of China's direct

investment in 20 countries of Africa from 2008 to 2014 is in a fluctuation trend and the average value is only 0.767. It reflects that whether an enterprise conducts effective innovation activities or not is an important constraint which influences efficiency improvement of China' s direct investment in Africa.

Year	*effch*	*techch*	*pech*	*sech*	*tfpch*
2008-2009	1.109	0.563	1.078	1.029	0.625
2009-2010	1.046	0.977	0.984	1.062	1.021
2010-2011	0.986	0.952	0.984	1.002	0.939
2011-2012	1.016	0.818	1.012	1.004	0.831
2012-2013	1.026	0.602	1.188	0.864	0.618
2013-2014	1.108	0.787	1.051	1.054	0.872
Average	1.047	0.767	1.047	1.000	0.803

Table 2. Malmquist Efficiency Index of China's Direct Investment in Africa from 2008 to 2014

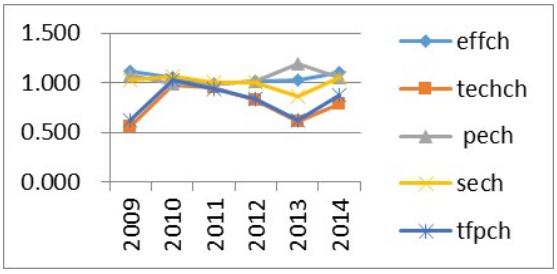

Figure 3. Malmquist Efficiency Tendency Chart of China's Direct Investment in Africa

Country Efficiency Analysis

The country efficiency of China's direct investment in 20 host countries of Africa from 2008 to 2014 is calculated by the Malmquist model and DEA P 2.1, and the result shown in Table 3 can be obtained. The 20 host countries are divided into the following types according to *tfpch*, *effch*, *techch*, *pech* and *sech* larger than, equal to or less than "1", of each host country in Table 3 and based on the classification rules of Figure 4.

Comprehensive Improving Host Countries (Such as Mauritius)

From 2008 to 2014, *tfpch*, *effch*, *techch*, *pech* and *sech* of China's direct investment in Mauritius were larger

than "1", wherein the efficiency of China's direct investment in Mauritius was improved by 9.0%. It indicates that China's direct investment in Mauritius is conducting effective innovation activities which

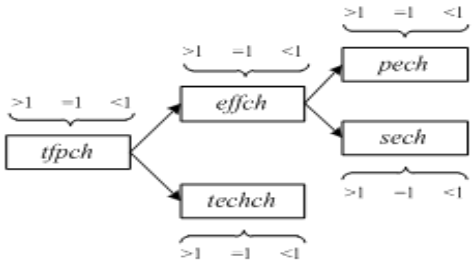

Figure 4. Classification of Dynamic Evaluation on Efficiency of China's Direct Investment in Each Host Country

advances the technical leading surface. Meanwhile, the scale of China's direct investment in Mauritius is reaching to the optimal scale. The level of Mauritius in utilizing the technology and management has also been promoted, which makes the technical efficiency of direct investment promoted. It is thus seen that advance of technical leading surface and improvement of technical efficiency make the overall efficiency of China's direct investment in Mauritius rapidly improved.

Technical efficiency promoting host countries, such as Chad

From 2008 to 2014, *tfpch* and *effch* of China's direct investment in Chad was larger than1, while *techch* was less than 1. It indicates that the technical leading surface of China's direct investment in the host countries was not propelled. However, the scale of China's investment in this kind of host countries is maintained in the optimal scale, the management level of Chad in absorbing and utilizing investment is constantly improved and the technical efficiency of China's direct investment in the country is improved, thus the overall efficiency of China's direct investment in this kind of countries is improved.

Technical leading surface retreating host countries, such as Zambia, Sudan, Congo (Kinshasa), Angola, Ghana, Tanzania, Kenya, Mozambique and Sudan

tfpch and *techch* of China's direct investment in these host countries are less than "1". It can be seen that retreating of technical leading surface is the main reason for reduction of overall efficiency of China' s direct investment in these host countries. It indicates that China' s direct investment in these host countries is lack

of effective innovation activities.

Technical leading surface retreating and technical efficiency reducing host countries, such as South Africa, Algeria, and Congo (Brazzaville)

tfpch , *effch* and *techch* of China's direct investment in these host countries are less than "1". It indicates that innovation of China's direct investment in these host countries is not enough and the technical efficiency of the direct investment is also declining. The decline comprises reduction of investment scale efficiency and reduction of the level in utilizing technology and management. The reasons from the two aspects have resulted in the reduction of the general investment efficiency.

In addition to these, it is found by further observing investment scale efficiency of these countries that: *effch* of China's direct investment in South Africa, Angola, Algeria, Mauritius, Egypt and Namibia is equal to "1", thus the investment scale and the technology utilization level is maintained in the optimal scale; while the *effch* of China's direct investment in Zambia, Nigeria, Ethiopia, Ghana, Tanzania, Zimbabwe, Mozambique, Guinea and Chad is larger than "1", thus the technical efficiency and investment scale are reaching to the optimal scale.

CONCLUSION

This paper selects top 20 host countries in the ranking of stock of China's direct investment in Africa by the end of 2014 as the evaluation objects from the perspective of the host countries, utilizes DEA model and Malmquist index method to calculate the overall efficiency and country efficiency of China's direct investment in Africa from 2008 to 2014 and analyzes the dynamic efficiency changes of China's direct investment in each host country of Africa. The following conclusions are obtained:

On the whole, the overall efficiency of China's direct investment in Africa is in the declined fluctuation trend, while from 2013 to 2014 it shows a rapidly rising trend. With improvement of technology absorbing and utilization level of the host countries, technical efficiency of China's direct investment has been constantly improved. Direct investment in most African host countries has reached or is reaching the optimal scale. However, lack of effective innovations in the process of China's direct investment has caused retreating of

the technical leading surface. Considering all the above factors, the overall efficiency of China's direct investment in the 20 countries from 2008 to 2014 shows a declined variation trend.

From the level of country difference, the efficiency of China's direct investment in a small number of host countries has been improved, but the efficiency of the direct investment in most host countries is in the declining trend. The reason for efficiency improvement comprises: improvement of the level of the host country in absorbing and utilizing technology and management of China's direct investment, innovation in the process of China's direct investment in the host country and the direct investment scale of the host country has reached or is close to the optimal scale. However, decline of overall efficiency of some host countries is because that China's direct investment is lack of effective innovation activities, the investment scale is improper and the level of absorbing and utilizing foreign investment technology is low.

SUGGESTIONS

According to the above conclusions, the following suggestions are proposed specific to the actual conditions of China's direct investment in each host country of Africa:

It is of necessity to adjust the scale of investment in the host countries and optimize the area selection in direct investment in Africa. Excessive investment scale and improper investment can be avoided by adjusting the investment scale. The direct investment efficiency can be optimized by enhancing agglomeration degree of the invested industries so that the optimal investment scale can be reached. For some of the host countries in Africa, South Africa, Zambia, Sudan, Ethiopia, Congo (Brazzaville), Egypt, Uganda and Guinea shall keep existing investment scale; while Algeria, Nigeria, Congo (Kinshasa), Zimbabwe, Angola, Namibia, Ghana, Tanzania, Kenya and Mozambique shall properly adjust existing investment scale to improve investment agglomeration degree and scale to realize optimal scale of direct investment in the host countries.

We should emphasize on supporting facilities of the invested project and connection with the industrial chain, improve the level of foreign investment utilization and technology spillover efficiency of the host countries. The level of most host countries of Africa in absorbing and utilizing the direct investment is low, which

directly results in reduction of the efficiency of China's direct investment in them. So in the process of investment in Africa, Chinese enterprises shall pay attention to supporting facilities of the invested projects and organic connection between upstream and downstream of the industrial chain. The enterprises are encouraged to enter into Africa "in group" and carry out cluster-type investment so as to enhance the industrial clustering ability and technology spillover effect of the investment in Africa and further promote efficiency level of China's direct investment in Africa. In consideration of the trend that Nigeria, Mauritius, Ghana and Ethiopia have constantly improved their levels of absorbing and utilizing the investment in recent years, China and Africa plan and jointly build the overseas industrial park and economic and trade cooperation areas to strengthen the industrial clustering ability and international competitiveness of enterprise investment.

Innovation of direct investment shall be implemented in Africa. Advance of technical leading surface can be promoted and the direct investment efficiency can be further promoted by innovations in entrance mode, investment industrial pattern and management manner of the direct investment in Africa. Besides, China shall also pay attention to adaption and innovation of technical localization of Chinese enterprises, encourage the Sino-African cooperation enterprises, establish and jointly build Sino-African economic and trade cooperation areas, industrial parks and special economic zones, enhance industry-university-research cooperation and promote industrial clustering ability of the direct investment.

We also need to strengthen infrastructure construction of the host countries and improve investment environment in Africa. Laggard infrastructure becomes the "bottleneck" which restricts economic development of Africa and foreign investment attraction. African countries have taken infrastructure construction as the acting point and important breakthrough point in developing economy and improving investment environment. With implementation of China's "One Belt and One Road" strategy, China and Africa have carried out major cooperation in infrastructure construction and capacity cooperation, which will greatly improve the investment environment of each host country in Africa and promote the overall efficiency of China's investment in Africa.

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ACKNOWLEDGMENT

This paper is a phased research result of the National Social Science Fund project "Research on Strategic Adjustment, Attraction Focus and Treatment of Overseas Investment of Chinese Enterprises in Africa under the Perspective of Spatial Economics" (Approval No.: 13BJL047).

Host Countries	*effch*	*techch*	*pech*	*sech*	*tfpch*	Host Countries	*effch*	*techch*	*pech*	*sech*	*tfpch*
South Africa	0.987	0.920	0.987	1.000	0.908	Ethiopia	1.239	0.766	0.990	1.252	0.949
Zambia	1.068	0.907	0.986	1.083	0.969	Tanzania	1.235	0.766	1.051	1.176	0.946
Nigeria	0.877	1.062	0.871	1.007	0.932	Congo (Brazzaville)	0.998	0.838	1.119	0.892	0.836
Angola	1.166	0.855	1.166	1.000	0.996	Kenya	1.045	0.764	1.057	0.989	0.799
Zimbabwe	1.129	0.713	1.075	1.050	0.805	Egypt	0.861	1.079	0.861	1.000	0.929
Sudan	1.009	0.749	1.066	0.946	0.756	Mozambique	1.196	0.611	1.092	1.095	0.731
Algeria	0.971	0.792	0.971	1.000	0.768	Uganda	1.242	0.515	1.449	0.857	0.639
Congo (Kinshasa)	1.121	0.715	1.143	0.981	0.801	Namibia	1.014	0.837	1.014	1.000	0.849
Mauritius	1.011	1.093	1.011	1.000	1.105	Guinea	1.649	0.603	1.171	1.408	0.994
Ghana	1.077	0.740	1.025	1.050	0.796	Chad	1.556	0.707	1.048	1.485	1.100

Table 3. Malmquist Efficiency Index of China's Direct Investment in Africa from 2008 to 2014

International Journal of Management, Economics and Social Sciences
Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017)
2018, Vol. 7(S1), pp.73 – 84.
ISSN 2304 – 1366
http://www.ijmess.com

What We Should Know about Patient Safety Culture: An Empirical Investigation of Viewpoints from Four Categories of Hospital Staffs in Taiwan

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In recent years, patient safety culture in healthcare organizations has been considered as a critical issue for improving the quality of healthcare. The current study attempts to examine the perceptions of patient safety from four different categories of hospital staffs in a case hospital by conducting the Chinese version of Safety Attitudes Questionnaire, developed from the Taiwan Joint Commission on Hospital Accreditation. Pearson correlation analysis is used to assess the strength and direction of the relationships among seven patient safety culture dimensions. For physicians and administrators, the findings highlight that safety climate is highly correlated to teamwork climate and perceptions of management. For nurses, the results reveal that safety climate is highly correlated to teamwork climate and working conditions. For technicians, job satisfaction is highly related to safety climate and working conditions. Additionally, emotional exhaustion is negatively significant to stress recognition and safety climate for all hospital staff.

Keywords: Safety attitudes questionnaire, Patient safety culture, Hospital staffs, Pearson correlation analysis

In 1995, the public health insurance only covered 60% of the population in Taiwan. In order to improve life and medical quality to all citizens, Taiwan' s government implemented a new National Health Insurance (NHI). Due to the implement of NHI, the citizens receive more benefits than ever, such as high-quality medical care and convenient access to treatment (Shieh, Wu, and Huang, 2010). Nowadays, Taiwan' s medical service system provides the public comprehensive health care. According to the annual report of the National Health Insurance Administration (NHIA), the NHI system now covers 99.6% of Taiwan's population

Manuscript received May 20, 2017; revised September 12, 2017; accepted October 28, 2017.
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in 2016 (NHIA, 2016). With the enhancement of medical quality, patients thus expect more care about the safety medical service provided (Lee and Hsieh, 2009; Ho and Lee, 2013). Evidence reveals that hospital staffs with higher attitudes toward patient safety are more likely to compete tasks as a team and emphasize the patient safety culture for healthcare organizations (Nie et al., 2013; Göethals et al., 2013; Lee et al., 2016). For example, Lee et al. (2016) have suggested that hospital staffs with positive patient safety can help healthcare organizations to reduce medical adverse events, such as patient fall, medical errors, and work absence. Hospital employees are the core staffs with professional skills, who dedicated to service patients in healthcare organizations (Liu et al., 2012; Lee et al., 2015). However, until now most studies have focused on the improvement of patient safety culture from the viewpoints of physicians and nurses (Abdi et al., 2015; Gozlu and Kaya, 2016; Lee et al., 2017), little knowledge has clearly recognized the difference of perceptions across different occupational categories of hospital staffs. In fact, physicians and nurses are more like to directly contact with patient than technicians and administrators. These hospital staffs may face different tasks and challenges in different medical environment (e.g. divisions, operating room, pharmacy, and front desk) and their attitudes toward patient safety may vary. Therefore, the current study aims to identify the opinions and attitudes toward patient safety from the viewpoints of four hospital staffs (i.e. physicians, nurses, technicians, and administrators) in order to comprehensively develop implications for improving patient safety culture.

Following this introduction, the second section of this paper presents a review of the literature on patient safety culture; the third section illustrates details of the methods used in the empirical investigation; the research results and discussion are demonstrated in section four and five respectively; and finally, the findings are concluded.

LITERATUE REVIEW

Patient safety culture in healthcare organizations has been considered a critical issue for improving the quality of healthcare (Michell et al., 2014; Lee et al., 2017). Patient safety culture was identified by the European Network for Patient Safety (EUNetPaS) in 2006 as ‘‘An integrated pattern of individual and organizational behavior, based upon shared beliefs and values that continuously seeks to minimize patient harm, which may result from the processes of care delivery’’ (EUNetPaS, 2006).

Studies have suggested that more benefits can be obtained if health organizations pay more attentions on the establishment of patient safety culture. For example, both Zuniga et al. (2013) and Nie et al. (2013) suggested that fewer hospital complications, patient falls, urinary tract infections and lower mortality are highly correlated to medical staffs with a positive attitude toward patient safety. Lee et al. (2016) also demonstrated that when the higher degree of burnout hospital staffs are identified, hospital management can make implementations to reduce the potential negative performance, including patient falls, medical malpractice, and medical errors. In fact, the medical errors and adverse events could result in a cost of harm to both patients and healthcare organizations (Longo et al., 2007; Ewing, 2013; Lee et al., 2015). It is therefore important for health organizations to evaluate patient safety in a regular period to continuously improve medical quality.

The Sexton et al.'s (2006) Safety Attitudes Questionnaire (SAQ) is most widely used to assess the attitudes toward patient safety in healthcare organizations (Nguyen et al., 2015; Lee et al., 2015). The SAQ questionnaire contains 30 items, categorized into six dimensions: teamwork climate (relationships and cooperation among staff), safety climate (organizational commitment to patient safety), job satisfaction (positive about work experience), stress recognition (stress factors that link to work performance), perceptions of management (administrator approval), and working conditions (perceived work-environment quality).

In 2014, the Taiwan Joint Commission on Hospital Accreditation (TJCHA) has modified the SAQ by incorporating two dimensions derived from the Maslach burnout inventory-human services survey (MBI-HSS). Particularly, nine questions were used to measure emotional exhaustion, and seven questions were used to measure work-life balance (Lee et al., 2016). Emotional exhaustion describes a loss of passion for work, emotional exhaustion and feelings of depersonalization (Poghosyan et al., 2009) whereas work-life balance refers to balancing both work and other aspects of life (Blunsdon et al., 2006; Feldtead et al., 2002). As a result, the Chinese version of SAQ contains eight dimensions and 46 questions, as shown in Table 1 (see Appendix-I).

METHODOLOGY

-Data Collection Procedure

The aim of current study is to examine the perceptions toward patient safety across different occupational categories of hospital staffs in a case hospital. This case hospital is one of the best general and teaching hospital in Taiwan (MOHW, 2015), which contains more than 30 divisions. Therefore, there is essential to access patient safety provided by the case hospital in continuous improvement of medical service.

As suggested by Hair et al. (2006), fifty hospital members are asked to answer a pretesting survey to confirm the accuracy and potential problems of the questionnaire. An online-based survey is consequently undertaken to investigate the perceptions toward patent safety among hospital staffs (i.e. physicians, nurses, technicians, and administrators) in the case hospital in 2016.

-Measurement

The Chinese version of SAQ is used to assess the perceptions toward patient safety among four different occupational categories. As presented in Table 1, seven dimensions with thirty nine items are assessed except work-life balance because the frequency scale is used to access that dimension. Six question items (questions 1 to 6) are used to measure teamwork climate; seven question items (questions 7 to 13) are used to measure safety climate; five question items (questions 14 to 18) are used to measure job satisfaction; stress recognition is accessed using four question items (question 19, 21, 25, and 26); perceptions of management is accessed using four question items (questions 27 to 30); working conditions is measured using four question items (questions 31 to 34); emotional exhaustion is measured using nine question items (question 20, 22, 23, 24, 35, 36, 37, 38, 39); work-life balance is measured using seven question items (questions 40 to 46). Additionally, hospital staffs are required to answer different questions due to dissimilar job tasks and working situations. For example, physicians and nurses are required to fill out thirty nine questions. For technicians and administrators, question items 2, 3, 4, 6, 8, and 30 are not required, and the number of questions is thirty three. Five-point Likert scales anchored by 1 (strongly disagree) and 5 (strongly agree) are used throughout the questionnaire. Eleven reversed questions are designed to further be more accurate in wording (Vandiver et al., 2002). Thus, each respondent' s answer is adjusted. The original answer of strongly agree represents the poorest perceptions of measuring outcome.

-Analysis Methods

Item analysis test (e.g. average test, standard deviation test, skewness test, and extreme groups test) is firstly assessed to verify the structure of the data (Wu and Tu, 2005). Pearson' s correlation analysis is subsequently performed to investigate the strength and direction of the relationships among seven patient safety culture dimensions (Cohen et al., 2013).

RESULTS

-Sample Characteristics

A total of 667 questionnaires are collected, while valid questionnaires are 588, representing an 88.16% return rate. In terms of sample profile, most hospital staffs are females except physicians (16.7% for physicians, 96.4% for nurses, 78.4% for technicians, and 69.5% for administrators). The majority respondent age is from 31 to 50 years old (64.6% for physicians, 3.0% for technicians, and 67.1% for administrators) whereas nurses' age ranges 21 to 40 years olds (78.4%). The characteristics also reveal that all respondents with relevant working experiences are more than five years in the hospital (64.7% for physicians, 48.4% for nurses, 60.8% for technicians, and 45.1% for administrators).

-Item Analysis

Average test that is accepted if the average should not fall on the average of total amount that is neither higher nor lower to more than 1.5 standard deviations (Wu and Tu, 2005). For four hospital staffs, the results demonstrate that the average of total amount are 3.63, 3.53, 3.51, and 3.35, the standard deviation are 0.590, 0.502, 0.511, and 0.578, respectively. The value should be neither greater than 4.52, 4.28, 4.28, and 4.22 nor less than 2.75, 2.78, 2.74, and 2.48. As a result, all items do pass the average test.

Results also show that the standard deviation of each of items is greater than 0.5, inspection of all items has satisfied the standard deviation test. Skewness test result indicates that the absolute values of skewness coefficient of all items are less than 1, which supports the skewness test. Moreover, the p-value of extreme groups for all items are less than 0.01 after independent sample t-test of average value in the extreme groups, indicating the support of extreme groups test.

-Descriptive Statistics

For nurses, technicians, and administrators, teamwork climate has the highest average value, whereas stress recognition has the highest average value followed by teamwork climate for physicians. For administrators, perceptions of management are identified as the second highest dimension of patient safety. For all four categories of hospital staffs, emotional exhaustion has the lowest average value. Overall, physicians have the highest attitude toward patient safety (total average value is 3.63) whereas administrators have lowest one (total average value is 3.35) (see Table 2). In addition, the results demonstrate that all dimensions' Cronbach's α values exceed 0.7 which indicates measuring scales have good reliability and internal consistency (Nunnally, 1978).

	Physicians (n=48)		Nurses (n=384)		Technicians (n=74)		Administrators (n=82)	
	Mean	**α**	**Mean**	**α**	**Mean**	**α**	**Mean**	**α**
1. TC	3.91	0.871	3.88	0.863	3.82	0.782	3.55	0.776
2. SC	3.71	0.905	3.73	0.891	3.73	0.845	3.44	0.853
3. JS	3.88	0.932	3.52	0.939	3.62	0.929	3.52	0.955
4. SR	3.96	0.860	3.69	0.882	3.53	0.899	3.35	0.861
5. PM	3.67	0.839	3.59	0.820	3.71	0.735	3.54	0.902
6. WC	3.62	0.891	3.59	0.899	3.63	0.775	3.39	0.902
7. EE	3.09	0.912	3.02	0.878	3.13	0.898	3.06	0.918
Total	3.63	0.955	3.53	0.941	3.51	0.930	3.35	0.942

Note: TC: teamwork climate; SC: safety climate; JS: job satisfaction; SR: stress recognition; PM: perceptions of management; WC: working conditions; EE: emotional exhaustion; α: Cronbach's alpha coefficient

Table 2: Average Value and Cronbach's Alpha Coefficient for Hospital Staffs

-Correlation Analysis

The Pearson correlation analysis is conducted to determine the degree of correlation among dimensions. On the basis of perspectives from physicians, the results illustrate that safety climate is highly correlated to teamwork climate and perceptions of management. For physicians, emotional exhaustion is negatively related to stress recognition and safety climate, from Table 3. For nurses, the results reveal that safety climate is highly correlated to teamwork climate and working conditions. Similarly, emotional exhaustion is negatively related to stress recognition and safety climate, as shown in Table 4. For technicians, job satisfaction is highly related to safety climate and working conditions. The correlation between emotional exhaustion and stress recognition, and safety climate is also negative, from Table 5. For administrators,

safety climate is highly correlated to teamwork climate and perceptions of management. A negative correlation between emotional exhaustion, stress recognition and safety climate is also found (see Table 6).

	1	2	3	4	5	6
1.TC						
2.SC	.815**					
3.JS	.799**	.867**				
4.SR	.049	.092	.058			
5.PM	.687**	.807**	.732**	.022		
6.WC	.701**	.871**	.820**	.005	.882**	
7.EE	.419**	-.437**	.370**	-.352*	.538**	.527**

Note: * $p < .05$; ** $p < .01$; TC: teamwork climate; SC: safety climate; JS: job satisfaction; SR: stress recognition; PM: perceptions of management; WC: working conditions; EE: emotional exhaustion

Table 3: Pearson's Correlation Analysis for Physicians (n=48)

	1	2	3	4	5	6
1.TC						
2.SC	.814**					
3.JS	.700**	.773**				
4.SR	-.003	.042	.023			
5.PM	.660**	.764**	.719**	.043		
6.WC	.674**	.780**	.702**	.056	.824**	
7.EE	.324**	-.312**	.363**	-.507**	.290**	.272**

Note: ** $p < .01$; TC: teamwork climate; SC: safety climate; JS: job satisfaction; SR: stress recognition; PM: perceptions of management; WC: working conditions; EE: emotional exhaustion

Table 4: Pearson's Correlation Analysis for Nurses (n=384)

	1	2	3	4	5	6
1.TC						
2.SC	.662**					
3.JS	.706**	.767**				
4.SR	.200	.054	.140			
5.PM	.569**	.677**	.671**	.210		
6.WC	.627**	.733**	.741**	.030	.701**	
7.EE	.310**	-.463**	.478**	-.307**	.411**	.451**

Note: ** $p < .01$; TC: teamwork climate; SC: safety climate; JS: job satisfaction; SR: stress recognition; PM: perceptions of management; WC: working conditions; EE: emotional exhaustion

Table 5: Pearson's Correlation Analysis for Technicians (n=74)

DISCUSSION

The results of our study are consistent with the study in Alves and Guirardello (2016) who indicated that indicated that emotional exhaustion is negatively correlated with safety climate or job satisfaction. The

Spearman's correlation values between emotional exhaustion and safety climate in terms of nurse are -0.32 and -0.312 in Alves and Guirardello (2016) and our study, respectively. Based on these results, the

	1	2	3	4	5	6
1.TC						
2.SC	.767**					
3.JS	.739**	.796**				
4.SR	.085	.092	.032			
5.PM	.736**	.896**	.762**	.129		
6.WC	.694**	.751**	.715**	.046	.781**	
7.EE	.391**	-.382**	.470**	-.372**	.377**	.304**

Note: ** $p < .01$; TC: teamwork climate; SC: safety climate; JS: job satisfaction; SR: stress recognition; PM: perceptions of management; WC: working conditions; EE: emotional exhaustion

Table 6: Pearson's Correlation Analysis for Administrators (n=82)

correlation of emotional exhaustion and safety climate is almost the same for Brazilian pediatric nurses and Taiwanese nurses in regional teaching hospital. However, for physicians, technicians and administrators, our study shows the correlation values of the two variables are -0.437, -0.463 and -0.382, respectively. The results indicate that the behavior of physicians protects the behavior of nurses. For example, as a supporter of physicians during operation, nurses may not disregard rules or guidelines regarding to safety climate if physicians follow guidelines during operation. Physicians and nurses are much more likely to directly collaborate with operating than other staffs such as technicians and administrators. In other word, technicians and administrators are more independent when working. Therefore, the more the perception on safety climate increases, the more the level of burnout increases for technicians. To decline the level of emotional exhaustion, a decrease on the workload and management on absenteeism are suggested (Alves and Guirardello, 2016). To enhance nurse on commitment to safety, Dawson et al. (2014) and Feng et al. (2011) suggested that the nurse manager shall show up in the working place. Therefore, feasible arrangement on human resources may be critical for the management in this regional teaching hospital.

Second, our results illustrate that emotional exhaustion is significantly related to stress recognition and Pearson's Correlation values are -0.352, -0.507, -0.307, and -0.372 in physicians, nurses, technicians and administrators, respectively. We can identify management of workload and absenteeism as two of the most important factors in stress of personnel (Alves and Guirardello, 2016). For example, when colleague is

absent, personnel who becomes as a substitute may increase workload and feel stressfully. Also, average value on emotional exhaustion is lowest among all seven variables in the questionnaire. In other words, staff always feels like working under extreme pressure in long term. This implies that the working environment and management on human resources in the hospital is an important issue to alleviate staff's level of emotional exhaustion.

Third, job satisfaction is highly related to teamwork climate or safety climate. In other words, as the job satisfaction of staffs increases, their teamwork climate or safety climate increases. Our results are similar with the study in Buljac-Samardzic et al. (2015). Buljac-Samardzic et al. (2015) investigated the safety attitude of caregivers in terms of nursing and residential homes. The correlation values between job satisfaction and teamwork climate in terms of nurses are 0.52 and 0.70 in Buljac-Samardzic et al. (2015) and our study, respectively. For the rest of three groups, the value is not less than 0.70 in our study. Furthermore, the correlation between job satisfaction and safety climate is also high among four groups and the value is not less than 0.767. The environment in this regional hospital where staffs work in is more complex than the environment in nursing and residential home intuitively. Therefore, comparing to staffs in nursing and residential home, staffs in this regional hospital may receive more satisfaction when they finish a mission. Also, the mission or environment in this regional hospital is more complex than it in nursing and residential home. The staffs in this regional hospital is more to work together and is more to follow guidelines to accomplish a mission rather than the staffs in nursing and residential home. Therefore the working environment and the difficulty of task are moderately assigned to each personnel instead of extremely easy or difficult so that either individual personnel or team may accomplish in appropriate manners to minimize patient safety risks.

CONCLUSION

This study aims to assess patient safety culture in terms of the viewpoints of four hospital staffs. To improve patient safety culture, human resource management is one of the most important issues in this regional teaching hospital. For all categories, emotional exhaustion and safety climate are significantly correlated and the result is consistent with the study in Alves and Guirardello (2016). For more details, rather than nurses, the correlation values of emotional exhaustion and safety climate are relatively higher for the other staffs,

i.e., physicians, technicians and administrators. The managers in healthcare organizations are suggested to improve staff's working environment. Without feasible arrangement on human resources, the staff who becomes as a substitute may increase workload and feel stressfully. Patient safety is the goal of a hospital. Therefore, top managers may put more efforts on alleviating staff's level of emotional exhaustion.

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ACKNOWLEDGMENT

This study was supported by Cheng Ching General Hospital – Chung Kang Branch with grant number of CH10200159, and Hubei University of Economics with the grant number of XJ16BS34.

Appendix-I

(1) Nurse input is well received in this clinical area
(2) In this clinical area, it is difficult to speak up if I perceive a problem with patient care(r)
(3) Disagreements in this clinical area are resolved appropriately (i.e. not who is right, but what is best for the patient)
(4) I have the support I need from other personnel to care for patients
(5) It is easy for personnel here to ask questions when there is something that they do not understand
(6) The physicians and nurses here work together as a well-coordinated team
(7) I would feel safe being treated here as a patient
(8) Medical errors are handled appropriately in this clinical area
(9) I know the proper channels to direct questions regarding patient safety in this clinical area
(10) I receive appropriate feedback about my performance
(11) In this clinical area, it is difficult to discuss errors(r)
(12) I am encouraged by my colleagues to report any patient safety concerns I may have
(13) The culture in this clinical area makes it easy to learn from the errors of others
(14) I like my job
(15) Working here is like being part of a large family
(16) This is a good place to work
(17) I am proud to work in this clinical area
(18) Morale in this clinical area is high
(19) When my workload becomes excessive, my performance is impaired
(20) I feel like I'm at the end of my rope(r)
(21) I am less effective at work when fatigued
(22) I feel burned out from my work(r)
(23) I feel frustrated by my job(r)
(24) I feel I'm working too hard on my job(r)
(25) I am more likely to make errors in tense or hostile situations (e.g. emergency resuscitation, seizure)
(26) Fatigue impairs my performance during emergency situations
(27) Managers supports my daily efforts27
(28) Managers do not knowingly compromise patient safety28
(29) I get adequate, timely information about events that might affect my work29
(30) The levels of staffing in this clinical area are sufficient to handle the number of patients
(31) Problem personnel are dealt with constructively
(32) This hospital does a good job of training new personnel
(33) All the necessary information for diagnostic and therapeutic decisions is routinely available to me
(34) Trainees in my discipline are adequately supervised
(33) I feel emotionally drained from my work(r)
(36) I feel used up at the end of the workday(r)
(37) I feel fatigued when I get up in the morning and have to face another day on the job(r)
(38) Working with people all day is really a strain for me(r)
(39) Working with people directly puts too much stress on me(r)
(40) Missed meals
(41) A hasty meal
(42) All-day work without any rest
(43) Individual or family plan change due to work factors
(44) Poor sleep
(45) Less than five-hour sleep at night
(46) Late work

Note: r: reversed question

Table 1: The Chinese Version of Safety Attitudes Questionnaire

International Journal of Management, Economics and Social Sciences
Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017)
2018, Vol. 7(S1), pp.85 – 108.
ISSN 2304 – 1366
http://www.ijmess.com

Selection of Guided Surgery Dental Implant Systems Using Network Data Envelopment Analysis

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All dental implant system suppliers typically claim the advantages and superiority of their product's specific attributes and functions. However, as assessment criteria are often inconsistent and conflicting, clinical dentists find it difficult to choose the most appropriate dental implant system. The present study used two-stage data envelopment analysis to measure the overall efficiency of individual dental implant systems and the relative efficiency of each phase of the selection process. The results of the present study can not only provide decision-making information for users, such as medical organizations, dentists, and patients, but may also inform guidelines for system producers to improve dental implant performance.

Keywords: Frontier projection, two-stage DEA, supplier selection, dental implant system

The introduction of computed tomography (CT) and development of the 3-dimensional implant planning software technology, CAD/CAM (computer-aided design/computer-assisted manufacturing), are undoubtedly important achievements in the field of dental implants (Wagner et al., 2001; Marchack, 2007; Chen et al., 2010). A thorough diagnosis, careful arrangement of implant position before surgery, and accurate implantation are critical for a predictable healing effect. Image-guided navigation surgery or stereographic surgical guidance using CAD-CAM technique is developed for this purpose. Currently, many software programs and hardware designed by different companies are available. (Ewers et al., 2004; Azari and Nikzad, 2008; Neugebauer et al., 2010).

Although dynamic systems were reported to provide more accurate guidance to users (Jung et al., 2009), they may cause more errors than static systems (Widmann, and Bale, 2006; Vercruyssen et al., 2008; Neugebauer et al., 2010). Today, there appears to be a trend toward static template - based guidance

Manuscript received May 20, 2017; revised August 11, 2017; accepted October 5, 2017.
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systems in dental implantology. To address the above mentioned conflict that higher accuracy dynamic systems do not ensure higher acceptance by users, manufacturers of systems should address " accuracy" from a production perspective and " acceptance" from a market perspective to ensure their survival and success. If the performances of different systems are assessed solely based on accuracy, a prejudiced outcome will be obtained. Thus, the present study attempted to balance these two aspects of performance-assessing criteria by employing two-stage data envelopment analysis (DEA). The first stage is referred to as the production-oriented phase and focuses on accuracy efficiency, while the second stage is referred to as the market-oriented phase and focuses on acceptance efficiency. The overall efficiency of this network model suggests the priority of system selection and also indicates potential improvements for manufacturers.

DEA is a linear programming technique used to evaluate the efficiency of decision-making units (DMUs) on the basis of multiple inputs and outputs (Butler and Li, 2005). As the input and output pre-assigned weights are derived from a mathematical model, without presumption on characterizing input and output variables, the results of DEAs are impartial and are immune from manipulation by subjective factors. However, the original DEA was unable to present important transformation and relationships between any two stages in a process while considering DMU as a " black box" (Sexton and Lewis, 2003; Cao and Yang, 2011). Conversely, Cook et al. (2010) posited that a network structure with intermediate measures is required, where outputs from the first stage become the inputs into the next stage in a process (Premachandra et al., 2012). One of the most studied and applied DEA network structures is a two-stage process (structure) where DMUs use inputs in the first stage to produce outputs (Chen and Zhu, 2017). Derived from the main concepts of multiple stage DEA, several DEA-based approaches have been used to examine supplier– buyer supply chain (or two-stage process) settings. (Cooper et al., 2011)

In dentistry, the selection of a CAD-CAM implant system is an application of supply chain management. The two-stage DEA model readily lends itself to the evaluation of the overall performances of system candidates and induces managerial implications on individual phases of process (Chen et al., 2010). In the present study, we aimed to determine an overall efficiency score for the entire process and calculate an efficiency score for each of the individual stages by means of employing the two-stage DEA model. Based

on frontier projection and peer benchmarking, the present study can provide system manufacturers with a clear indication of the strengths and weaknesses of both production and market acceptance stages.

The present manuscript is presented in five sections. The rest of the sections are organized as follows. Section 2 gives an overview of two-stage DEA and DEA in medical applications. Section 3 delineates the present research methodology. Section 4 presents an empirical study and associated results. Conclusions and recommendations for further research are made in the Section 5.

LITERATURE REVIEW

- Surgical Implant Dentistry

According to the 2005 survey of the Bureau of National Health Insurance in the Department of Health in Taiwan, only 56.5% of citizens between 12 and 64 years of age had 28 teeth, whereas the rest had false or missing teeth and dental implants. The average number of lost teeth was 3.5, with only 20% of people aged >65 years having all 28 original teeth. In this population, the average number of lost teeth was 14.8. Meanwhile, the average number of lost teeth among citizens aged 12 was 5.6 (Tsai, 2009).

Dental implantation has a history of over 50 years since 1960. From the very beginning, this approach has focused on implant fixtures that can achieve osseointegration. To date, the approach aims to shorten the time to osseointegration while demanding that the implant position matches with the future filling material on the surface and integrates well with gums, alveolar bone, and surrounding teeth to ensure the need for beauty and function. To achieve the above mentioned demands, the location, angle, and direction of implant fixtures are critical (Kopp, 2003; Vercruyssen et al., 2008).

The development of computer-assisted surgical guidance and compute-navigated surgeries has shortened the osseointegration time, reduced treatment and waiting time, and allowed the performance of minimally invasive surgery with immediate recovery and little bleeding without the requirement for incisions or suturing (Valente et al., 2006). This approach can postoperatively reduce patient discomfort and allow precise treatment. The implant fixture can be placed in an ideal position that facilitates optimal fabrication of prostheses. Surgical damage to the surrounding anatomic structures, such as the maxillary sinus and nerves

of the mandibular alveolar bone, can be prevented. Thus, the safety of surgery is enhanced (Schneider et al., 2006; Kero, et al., 2010).

When used as implant positioning devices, computer-assisted guidance systems can be categorized into "static" and "dynamic" systems (Jabero and Sarment; 2006; Schneider et al., 2006; Neugebauer et al., 2010).

- Dynamic system: computer-assisted surgical navigation, which adopts a navigation system to assist dental implant surgery, was first used in stereotactic neurosurgery and then adopted by other medical areas. It can discern the location of pathological changes and anatomic structures. During the process of dental implantation, the navigation equipment is set by the dental chair (Ewers et al., 2004; Ewers et al., 2005). Before surgery, the dentist can perform spatial registration by using the specific anchor point for arrangement on the navigation system. During surgery, CT scanning images are connected with patient images so the process of dental implantation can be seen on the screen. The relative position and angle of the simulated implant and the drill bit during ongoing drilling can be simultaneously observed. Important organs can be marked by special software to enhance patient safety. Last, the dentist can insert the implant precisely into jawbone. The navigation system also allows the dentist to change plans and adjust the implant to a more suitable position according to clinical experience (Widmann et al., 2005; Widmann and Bale, 2006; Casap et al., 2008).
- Static system: computer-assisted surgical guidance can be divided into two types according to the means of production.

Stereolithography (STL) Surgical Template:

The patient has to wear a suitable image guide and undergoes CT scanning. The DICOM file is recombined as a 3D image with the patient model of jawbone or simulated surgical guidance by rapid prototyping (Sohmura et al., 2009). Rapid prototyping is based on non-traditional methods. The computer-assisted design software helps to produce a 3D image. This image is transformed into STL file, and the STL file is uploaded to the rapid prototyping system, which can divide the scopes according to the user and create a model, layer by layer.

Rapid prototyping machine development has gradually attracted the attention of scholars and industries, predominantly as these machines can reduce the surgery duration. Further, this system can be easily adopted and is suitable for various products. This type of template adopts a guide tube for drill bit guidance (Fortin et al., 2002; Fortin et al., 2004). Clinically, a guide tube with a comparable diameter to the drill bit is adopted to limit the drill bit direction. A template can have several guide tubes with different diameters for replacement and can also create several templates with different guide tubes of differing diameter for the replacement of drill bit to improve guidance (Sarment et al., 2003).

This method is more convenient than navigation before surgery and more similar to the traditional process of dental implantation. Further, this approach is commonly adopted because it is easily understood and accepted by dentists.

Computer-Driven Drilling Surgical Template:

Patients have to wear special image navigating templates before undergoing CT scanning. Then, a DICOM file is recombined and planed by professional software. The special navigation device on the image navigation template is used for spatial navigation and the planed implant is transferred to the drill bit and drilling system (Chen, 2010). On the patient's plaster cast, drilling is initiated in accordance with the planned position. Last, the guide tube is added and the template is completed. During surgery, the drill bit is guided by a relative guide tube of differing diameter (Klein and Abrams, 2001).

- Two-Stage DEA

In recent years, a myriad of DEA studies have focused on two-stage processes (Chen et al., 2010). In the past, traditional DEA was only able to estimate the relative efficiency of a sole step of the process for DMUs. Instead, this approach considers the production process of a DMU as a black box, which does not completely represent the reality of the efficiency of the various stages of the process of the DMU as part of a continuous set of activities. Therefore, two-stage DEA may allow assessment of the actual operational efficiency of the DMU. (Liu et al., 2012; Lozano et al., 2012).

The two-stage DEA is a form of network DEA. The network DEA model originated by Färe and Grosskopf (1996) is built around the concept of sub-technologies within the "black box" of DEA. Färe and Grosskopf deem the production process as a network, which includes three parts: inputs, outputs, and intermediate

products. Furthermore, intermediate products refer to the concept of transformation from input to output. This concept can be used to provide a complete DMU assessment through all aspects of the decomposition of the production process. (Cooper et al., 2011).

Seiford and Zhu's (1999) initiatively applied two-stage DEA for evaluating US commercial bank operational performance in a two-stage process, characterized by profitability and marketability. In their study, profitability was measured in the first stage using labor and assets as inputs and profits and revenues as outputs. In the second stage for marketability, the profits and revenue were then used as inputs, while market value, returns, and earnings per share constituted the outputs. Chilingerian and Sherman (2004) described a two-stage process in measuring physician care. Their first stage is a manager-controlled process with inputs including registered nurses, medical supplies, and capital and fixed costs. These inputs generate the outputs or intermediate measures, including patient days, treatment quality, and drugs dispensed among others. The outputs of the second physician-controlled stage include research grants, patient status, and quantity of individuals trained according to specialty. Abad et al. (2004) took advantage of two-stage DEA to profile 30 stocks in the Spanish manufacturing industry between 1991 and 1996.

Recently, numerous applications of two-stage DEA have extended into a variety of industries and research communities. For example, Fukuyama and Weber (2010) used a slacks-based inefficiency measure for a two-stage system with bad outputs to estimate the performance of Japanese banks. Andrew and Leon (2011) used the two-stage DEA to determine the efficiency of warehousing industry. Zha et al. (2012) used a two-stage DEA model with feedback developed to evaluate team performance, efficiencies of the operating environment, team members, and their impacts on overall efficiency. Premachandra et al. (2012) proposed a novel two-stage DEA model that decomposes the overall efficiency of a DMU into two components and demonstrated its applicability by assessing the relative performance of 66 large mutual fund families in the US over the period 1993–2008.

In summary, two-stage DEA can provide useful insights for solving managerial problems in the real world. This approach is applicable in a variety of industries and interdisciplinary issues, including medical supplier selection, the main topic of the present study.

- DEA in Medical Applications

DEA has been developed as a powerful quantitative and analytical tool for evaluating the efficiency over 30 years. After the initial study of Cooper and Rhodes was published, this trend has continued (Cooper et al., 2011). There are numerous scholars who devise new DEA models to improve the evaluation of efficiency, and DEA has matured and become widely adopted (Liu et al., 2012). DEA was introduced to the health-care industry in 1986 (Banker et al., 1986). Banker et al. (1986) evaluated world-wide medical service and the efficiency of medical organizations based on multiple qualitative and quantitative measurements.

In recent times, DEA application to world-wide medical services remains fruitful and promising. Huang (1989) used a CCR model to perform a multidisciplinary evaluation of different organizational approaches to rural primary health-care delivery from 1978 to 1983. DEA has been used by heterogeneous organizations for cost accounting, production, and regression analysis. In Northern Ireland, Mckillop et al. (1999) estimated the technical, scale, and size efficiency of acute hospitals over 1986–1992, concluding to expand larger hospitals and restructuring/closing smaller hospitals, and indicating that the expansion of large hospitals may not yield substantial efficiency gains. Puig-Junoy (2000) used CCR, BCC, and Assurance Region (AR) approach to evaluate the efficiency of 94 acute care hospitals in Spain and explored the influence of hospital environment on efficiency. This study adopted a two-stage approach of DEA and a regression model to analyze the production and cost frontier of 94 acute care hospitals. This paper used a homogeneous method of partitioning cost efficiency into the DEA and efficiency measurement literature by adding results.

The efficiency and productivity of the hospitals in an Austrian province from 1994 to 1996 were studied by Maria (2002). Maria used two models and obtained differing results. An average efficiency of 96% by the first model with conservative output measurement and that of 70% from the other model with credit points was calculated. From 1994 to 1996, the average efficiency in the first model was stable; however, in the other model, efficiency regularly increased. Thus, efficiency change over time differently develops and needs to be screened for (Hofmarcher, et al., 2002). Brenda (2005) adopted DEA and Stochastic Frontier Analysis (SFA) to assess the efficiency of acute public hospitals in Ireland between 1995 and 2000. This study was the first to estimate the average efficiency of hospitals in Ireland and emphasize the variation in technical efficiency among hospitals. Wei et al. (2011) adopted cross-sectional and longitudinal efficiency analysis models to analyze the operational efficiency of medical centers. They further constructed managerial decision-making

path models and analyzed the level of hospitals in various managerial decision-making path models and identified paths to be improved in Taiwan.

The above mentioned-references indicate that DEA is mostly used by medical services for the evaluation of efficiency of medical organizations (sun and Luo, 2017; Barouni, 2016). There are few studies that have adopted DEA in assessing medical facility performance.

- The Technology Acceptance Model

The technology acceptance model (TAM) was proposed by Davis (1989). A subsequent study by Davis et al. (1989) was based on the theory of reasoned action (TRA) (Fishbein and Ajzen, 1975), which as an instrument used to predict the likelihood of a new technology being adopted within a group or an organization (Turner et al., 2010).

TAM is founded upon the hypothesis that technology acceptance and use can be explained in terms of user's internal beliefs, attitudes, and intentions, and found that it could better explain user's acceptance of information technology. Two important concepts of TAM are perceived usefulness and perceived ease of use (Davis, 1989). Perceived usefulness means that the subjective recognition of the user on certain information systems can enhance the efficiency of work. Perceived ease of use refers to the time required for a user to familiarize themselves with a certain system. Figure 1 illustrates the TAM model.

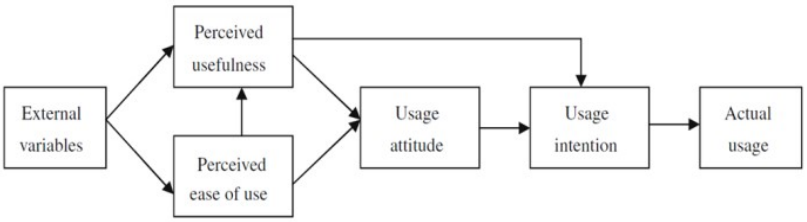

Figure 1. The Technology Acceptance Model

Numerous empirical studies have found TAM to be a robust and parsimonious model for the explanation of technology usage (Lee et al., 2003) in areas including m-commerce (Pavlou, 2003; Bruner and Kumar, 2005), email, banking technology, online games, and enterprise resources planning (ERP) systems (Gefen, Karahanna, & Straub,2003). TAM has also been applied in health care and conducted in a wide variety of

countries. Several studies have been conducted in the UK (Van Schaik et al., 2002; Barker et al., 2003), the mainland US (Liu & Ma, 2005), Australia (Schaper and Pervan, 2007), and Taiwan (Tung et al., 2008).

The present study applied the concept of the TAM to construct a system selection preference matrix and aimed to provide users with an important basis for selecting or evaluating systems.

METHODOLOGY

- Frontier Projection Two-Stage DEA

Chen et al. (2010) posited that the previous two-stage models in literature were unable to provide an efficiency frontier or the correct relative efficiency for every DMU because they do not address potential conflicting roles of intermediate measures between the two stages. Further, the second stage may have to reduce its inputs (intermediate measures) to achieve an efficient status; however, this would imply reduction in the first stage outputs, thereby reducing the efficiency of that stage. A number of DEA studies have been performed in an attempt to address this type of conflict (Liang et al., 2008). A number of authors, including Chen and Zhu (2004) and Chen et al. (2006) have presented a linear DEA type model where the intermediate measures are set as decision variables. However, their individual stage efficiency scores do not provide information on the overall performance and best-practice of the two-stage process. Similarly, the model of Kao and Hwang (2008), via adjusting the inputs and outputs by the efficiency scores in a two-stage process, is generally insufficient to yield a frontier projection.

Chen et al. (2010) developed a two-stage model based upon the assumption of constant returns to scale (CRS). A generic two-stage process, as shown in Fig. 3-1, can be applied to each of a set of n DMUs. If each DMU_j (j = 1, 2,..., n) is assumed to have m inputs x_{ij} (i = 1, 2,..., m) to the first stage, and D outputs z_{dj} (d = 1, 2,..., D) from that stage, these D outputs then become the inputs to the second stage, and therefore, behave as intermediate measures. The outputs from the second stage are y_{rj} (r = 1, 2,..., s).

For DMU_j, the study denotes the efficiency ratios for the first stage as θ_j^1 and the second as θ_j^2. Below are the definitions of θ_j^1 and θ_j^2

$$\theta_j^1 = \frac{\sum_{d-1}^{D} w_d z_{dj}}{\sum_{i=1}^{m} v_i x_{ij}} \text{ and } \theta_j^2 = \frac{\sum_{r-1}^{s} u_r y_{rj}}{\sum_{d=1}^{D} \tilde{w}_d z_{dj}}$$

Where $v_i, w_d, \tilde{w}_d$ and u_r are unknown non-negative weights , $w_d = \tilde{w}_d$

The two-stage overall efficiency ratio is defined as $\theta_j^1 \cdot \theta_j^2$ which is equal to $\theta_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$.

Input-Oriented Model

For each DMU_0, Chen et al. (2010) introduce $\tilde{z}_{d0}\ (d = 1, \ldots D)$, representing a set of new intermediate measures to be determined, then break the constraints $\sum_{j=1}^{n}(\lambda_j - \mu_j) z_{dj} \geq 0$ into two new sets of constraints as the below, to revise the model by Kao and Hwang (2008).

$$\sum_{j=1}^{n} \lambda_i z_{dj} \geq \tilde{z}_{d0}, \qquad d = 1,2,\ldots,D,$$

$$\sum_{j=1}^{n} \mu_i z_{dj} \geq \tilde{Z}_{d0}, \qquad d - 1,2,\ldots,D,$$

$$\lambda_i, \mu_i \geq 0, \qquad i = 1,2,\ldots,m$$

The first new set of constraints treats the $\tilde{z}_{d0}$ as "outputs". and the second set treats the $\tilde{z}_{d0}$ as "inputs". They propose the DEA type model as

Min $\tilde{\theta}$

s.t.

$$\sum_{j=1}^{n} \lambda_i x_{ij} \leq \tilde{\theta} x_{i0}, \qquad i = 1,\ldots,m,$$

$$\sum_{j-1}^{n} \mu_j y_{rj} \geq y_{r0}, \qquad r = 1,\ldots,s,$$

$$\sum_{j=1}^{n} \lambda_i z_{dj} \geq \tilde{z}_{d0}, \qquad d = 1,\ldots,D,$$

$$\sum_{j=1}^{n} \mu_i z_{dj} \leq \tilde{z}_{d0}, \qquad d = 1,\ldots,D,$$

$$\tilde{z}_{d0} \geq 0, \ d = 1,\ldots,D,$$

$$\lambda_i \geq 0\ , \qquad j = 1, \dots, n,$$

$$\mu_i \geq 0\ , \qquad j = 1, \dots, n,$$

$$\tilde{\theta} < 1. \quad (1)$$

The dual can be expressed as:

$$\text{Max} \quad \sum_{r=1}^{s} u_r y_{r0}$$

$$s.t. \quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{d=1}^{D} w_d^2 z_{dj} \leq 0\ , \qquad j = 1,2, \dots, n,$$

$$\sum_{d-1}^{D} w_d^1 z_{dj} - \sum_{i-1}^{m} v_i x_{ij} \leq 0\ , \qquad j = 1,2, \dots, n,$$

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$

$$W_d^2 - W_d^1 \leq 0, \qquad d = 1,2, \dots, D$$

$$W_d^1, W_d^2 \geq 0,\ d = 1,2, \dots, D;\ v_i \geq, i = 1,2, \dots, m;\ u_r \geq, r = 1,2, \dots, s \quad (2)$$

Output-Oriented Model

A general model of the output-oriented version is given by

$$\text{Min} \frac{\sum_{i=1}^{m} v_i x_{ij0}}{\sum_{r=1}^{s} u_r y_{rj0}}$$

$$\text{s.t. } \theta_j^1 < 1 \text{ and } \theta_j^2 \leq 1 \text{ for all } j,$$

For each DMU_0, the relative efficiency can be derived by the below optimization model which specifies as

$$\text{Min} \sum_{i=1}^{m} v_i x_{i0}$$

$$\text{s.t.} \sum_{r-1}^{s} u_r y_{rj} - \sum_{d-1}^{D} W_d Z_{dj} \leq 0\ , \qquad j = 1,2, \dots, n,$$

$$\sum_{d=1}^{D} w_d z_{dj} - \sum_{i=1}^{m} v_i x_{ij} < 0, \qquad j = 1,2,\dots,n,$$

$$\sum_{r=1}^{s} u_r y_{r0} = 1,$$

$$\sum_{j=1}^{n} \lambda_i z_{dj} \geq \tilde{z}_{d0}, \qquad d = 1,\dots,D,$$

$$\sum_{j=1}^{n} \mu_i z_{dj} \leq \tilde{z}_{d0}, \qquad d = 1,\dots,D,$$

$$W_d, d = 1,2,\dots,D;\ v_i, i = 1,2,\dots,m;\ u_r, r = 1,2,\dots,s \geq 0. \qquad (3)$$

The dual can be expressed as:

Max $\tilde{\emptyset}$

$$\text{s.t.} \sum_{j=1}^{n} \lambda_i x_{ij} \leq x_{i0}, \quad i = 1,\dots,m$$

$$\sum_{j=1}^{n} \mu_j y_{rj} > \tilde{\emptyset} y_{r0}, \qquad r = 1,\dots,s,$$

$$\sum_{j=1}^{n} \lambda_i z_{dj} \geq \tilde{z}_{d0}, \qquad d = 1,\dots,D,$$

$$\sum_{j=1}^{n} \mu_i z_{dj} \geq \tilde{z}_{d0}, \qquad d - 1,\dots,D,$$

$$\tilde{z}_{d0} \geq 0, \quad d = 1,\dots,D,$$

$$\lambda_i \geq 0, \quad j = 1,\dots,n,$$

$$\mu_i \geq 0, \quad j = 1,\dots,n,$$

$\emptyset \geq 1$ (4)

From models (2) and (4), it can be seen that a set of optimal intermediate measures (z), individual stage, and overall efficiency scores are obtained.

In the dental implant system selection setting, factors such as ease of intraoperative handling and relative inexpensiveness are determinants of clinician willing to choose a system and an indication of market acceptance, which is also a major concern of system manufacturers regarding competitive advantage. Therefore, an output-oriented model was applied in the present study.

- Determination of Inputs, Intermediate Measures and Outputs

The assessment was divided into two stages: perceived usefulness and clinician acceptance. The former focused on the relative efficiency of accuracy of peer equipment, while the later focused on that of the acceptance of systems used by clinical dentists (Figure 2).

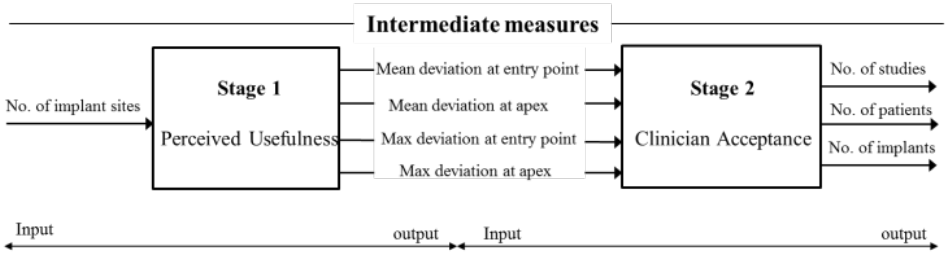

Figure 2. Dental System Selection Process

- Definition of Input in Stage 1

As the system accuracy reported by Jung et al. (2009) is a result of a meta-analysis derived from the number of implant sites, it is likely to be influential as an input factor in stage 1.

The number of implant sites refers to the amount of implant placements or drill holes in models, cadavers, and humans. The operational definition of the number of implant sites is the sum of the sites of systems in the reference article.

- Definitions of Intermediate Measures

The dental implant is an important choice of treatments for edentulous as well as partially edentulous patients as a definitive treatment. In patients not considered to be in a good condition for surgery or in whom anatomical treatment is likely to be challenging, precise implant surgery is absolutely necessary (Weitz et al., 2011). The position of the implant fixture is typically the key aspect of the entire implant surgery. Deviation of the implant may not only cause damaged perceptional nerves but also permanent abnormal perception or paralysis (Vercruyssen et al., 2008). Hence, a precise scheme of treatment can reduce the occurrence of complications and shorten the time required for treatment and recovery (Serrano et al., 2008). Successful dental implant is based on both proper osseointegration and the optimal position of the implant to provide aesthetics and function (Kopp et al., 2003; Widmann et al., 2005). The accuracy of implant is a reverse estimate of the overall deviation from the commencement to the completion of the placement. Deviation may occur at any stage and worsen over time. Therefore, studies that analyze the accuracy variables of implant position focused on deviation at the entry point of the implant, at the apex of the implant, in height, and of the axis of the drill or implant, as illustrated in Figure 3 (Schneider et al., 2006 and Van Assche et al., 2012). Owing to the absence of deviation in height and angle [(3) and (4) in Figure 3] in Jung's report, only two variables, deviations at entry point and apex, were available and used as the undesired outputs of stage 1 of the DEA in the present study.

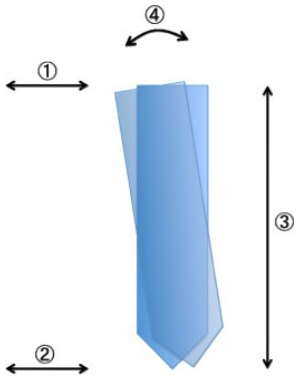

Figure 3. Operation Variables of Intermediate Measures

Direction of deviations in the variables of accuracy : (1) deviation at entry point, (2) deviation at apex, (3) deviation in height, and (4) angular deviation (Schneider et al., 2006).

Moreover, dentists are most concerned about the largest deviations that may occur in specific system. In dynamic or static systems, unacceptable and out of tolerance deviation may occur (Chen, 2010). From the viewpoint of patient security and laws, this type of deviation can be a serious risk once it has occurred. Thus, the largest deviation should be the major concern of dentists (Vercruyssen et al., 2008).

Therefore, the present study used four variables as outputs in stage 1 and inputs in stage 2 (i.e., intermediate measures). The definitions of these intermediate measures are as follows:

1. Mean deviation at entry point: Deviation error in a horizontal direction at the entry point of the drill or implant.
2. Mean deviation at apex: Deviation error in a horizontal direction at the apex of the drill or implant.
3. Max deviation at entry point: Deviation error in a horizontal direction at the entry point of the drill or implant causing the largest deviation via meta-regression analysis according to references.
4. Max deviation at apex: Deviation error in a horizontal direction at the apex of the drill or implant causing the largest deviation via meta-regression analysis according to references.

- Definitions of Outputs in Stage 2

1. The number of studies: The number of studies every system used in Jung's (2009) report on clinical outcome.
2. The number of patients: The number of patients every system used in Jung's (2009) report on clinical outcome.
3. The number of implants: The number of implants every system used in Jung's (2009) report on clinical outcome.

Logically, these three factors are indicators of clinician acceptance. Higher value in any of these variables indicates greater utilization of these systems in clinics. Market acceptance is the estimate goal of equipment vendors and users. Factors such as ease of intraoperative handling and relative inexpensiveness are determinants of clinician willing to choose a system, and also an indication of market acceptance, which is major concern of system manufacturers regarding competitive advantage. Therefore, the output-oriented model, which emphasizes output performance, was deemed appropriate for use in the present study.

RESULTS

We applied the data of Jung et al. (2009) to the software, DEAFrontier_OpeanSolver.xlam, developed in 2012 by Joe Zhu to conduct an empirical analysis.

The missing values for the mean apex and max apex of DMU6 were replaced with the meta-mean of dynamic principle members. The result is shown in Table 1.

DMU No.	DMU Name	No. of sites	Mean entry	Mean apex	Max entry	Max apex	No. of studies	No. of patients	No. of implants
Static Principle									
1	Nobel	28	0.89	0.99	1.16	1.26	2	57	347
2	Simplant	121	1.26	1.97	1.74	2.97	1	5	32
Dynamic Principle									
3	Treon	224	0.9	0.6	1.49	0.73	3	53	198
4	Robodent	15	0.35	0.47	0.44	0.56	1	20	71
5	Visit	99	0.72	0.99	0.91	1.37	2	28	122
6	Vector Vision	240	0.95	0.68	0.98	0.8	2	23	82
Mean		121.1667	0.8450	0.95	1.12	1.2817	1.8333	31	142
Median		110	0.8950	0.835	1.07	1.03	2	25.5	102

Table 1. The Original Data

As the outputs of stage 1 and inputs of stage 2 are undesirable deviations, we modified the DEA to overcome weaknesses in dealing with negative undesirable factors as follows: (Tseng, 2006)

1. To apply negative signs to undesirable factors to change to positive values and then adopt a DEA model to calculate efficiency.
2. To apply negative signs to undesirable factors and move the last number to change values to positive and then use a DEA model to calculate efficiency.
3. To take undesirable outputs as inputs and undesirable inputs as outputs.
4. To find the reciprocal of undesirable factors and deal with each in the DEA model.
5. To use the weak disposable model developed by Fare et. al. (1989) to evaluate the output loss.

In the present study, due to the characteristics of the data, it was deemed unreasonable to apply methods other than the reciprocal approach. The transformation of undesirable variables using the reciprocal approach is shown in Table 2.

DMU No.	DMU Name	No. of sites	Mean entry	Mean apex	Max entry	Max apex	No. of studies	No. of patients	No. of implants
Static Principle									
1	Nobel	28	1.1236	1.0101	0.8621	0.7937	2	57	347
2	Simplant	121	0.7937	0.5076	0.5747	0.3367	1	5	32
Dynamic Principle									
3	Treon	224	1.1111	1.6667	0.6711	1.3699	3	53	198
4	Robodent	15	2.8571	2.1277	2.2727	1.7857	1	20	71
5	Visit	99	1.3889	1.0101	1.0989	0.7299	2	28	122
6	Vector Vision	240	1.0526	1.4706	1.0204	1.2500	2	23	82
Mean		121.1667	1.3878	1.2988	1.0833	1.0443	1.8333	31	142
Median		110	1.1174	1.2403	0.9412	1.0218	2	25.5	102

Table 2. Transformed Data

Two-Stage Frontier Projection

We applied the transformed empirical dataset to the output-oriented two-stage model for frontier projection. Overall efficiency scores obtained from the output-oriented model can also be considered an expansion factor. Therefore, the relative efficiencies of DMUs are the reciprocal of expansion factors, which are summarized in Table 3.

As shown in Table 3, all 6 systems inefficiently performed in both networked stages, and no system had a perfect overall efficiency score of 1. The mean overall efficiency score and highest overall efficiency score were 0.1117 and 0.2543, respectively, for the Nobel system, which is a member of the Static principle. This score was followed by 0.2373 for Robodent and 0.0719 for Visit, members of the Dynamic principle. These results indicate substantial room for improvement in system efficiency. Among all the evaluated DMU, only Nobel and Robodent had above-average efficiency. Besides, Vector Vision and Simplant had efficiency scores of only 0.0297 and 0.0294.

DMU No.	DMU Name	Output-oriented scores	1/Output-oriented scores
Static Principle			
1	Nobel	3.9319	0.2543
2	Simplant	33.9830	0.0294
Dynamic Principle			
3	Treon	20.9702	0.0477
4	Robodent	4.2128	0.2374
5	Visit	13.9021	0.0719
6	Vector Vision	33.7021	0.0297
Mean		18.4504	0.1117
Median		17.4362	0.0598

* 1/Output-oriented scores = relative efficiency

Table 3. Output-Oriented Overall Efficiency Scores

Perceived Usefulness Efficiency and Clinician Acceptance Efficiency

After decomposing the overall scores, two efficiency scores were derived: perceived usefulness efficiency and clinician acceptance efficiency, respectively, referring to the first stage and second stage of this networked model (Table 4).

DMU No.	DMU Name	Perceived Usefulness		Clinician Acceptance	
		Scores	1/Scores	Scores	1/Scores
Static Principle					
1	Nobel	3.9319	0.2543	1.0000	1.0000
2	Simplant	33.8114	0.0296	1.0051	0.9949
Dynamic Principle					
3	Treon	19.0638	0.0525	1.1000	0.9091
4	Robodent	1.0000	1.0000	4.2128	0.2374
5	Visit	13.9021	0.0719	1.0000	1.0000
6	Vector Vision	23.1489	0.0432	1.4559	0.6869
Mean		15.8097	0.2419	1.6290	0.8047
Median		16.4830	0.0622	1.0525	0.9520

Table 4. Perceived Usefulness Efficiency and Clinician Acceptance Efficiency

Robodent from the dynamic principle had the highest efficiency in perceived usefulness, which indicates it was efficient at this stage. The second was Nobel from the static principle, whose efficiency was 0.2543. In this stage, only these two systems had efficiency above the average of 0.2419. In the stage of clinician acceptance, Nobel and Visit were found to be more easily accepted by doctors. Simplant had a high score of 0.9949. We found that Nobel and Simplant were static principle members. At this stage, the mean score of the static principle was higher than that of the dynamic principle.

In both perceived usefulness and clinician acceptance stages, we observed an interesting phenomenon. Robodent had the highest score in perceived usefulness but the lowest score of 0.2373 in clinician acceptance. In perceived usefulness, most systems of the dynamic principle had scores higher than the static principle. As each system has its own strengths and weaknesses in different dimensions involved with its sub-processes, the present study attempted to construct a system selection preference matrix to discover the merits of each system by comparing clinician acceptance to perceived usefulness. We employed the medians of these two dimensions (0.0622 and 0.9520, respectively) for perceived usefulness and clinician acceptance, to categorization systems into four quadrants; top-priority, customer-preferred, least-priority, technology-preferred (Figure 4).

In top-priority quadrants, there were two systems, Nobel and Visit, which performed well in both aspects of technology and usefulness. As systems in customer-preferred, for example Simplant, favor the easiness of use, the enhancement of accuracy should be considered to increase their competitiveness. In least-priority, Treon and Vector Vision were found to need enhancements in both acceptance and accuracy. Although Robodent, found to lie in the technology-preferred quadrant indicating high implant accuracy, had the highest score of efficiency in perceived usefulness, it overlooks the convenience of usage of clinical facilities.

According to the results of the present study, clinical doctors place greater emphasis on convenience of usage. Although dental implant suppliers place importance on accuracy, clinician doctors do not choose the most accurate system. Thus, we suggest that system suppliers should not only enhance accuracy on

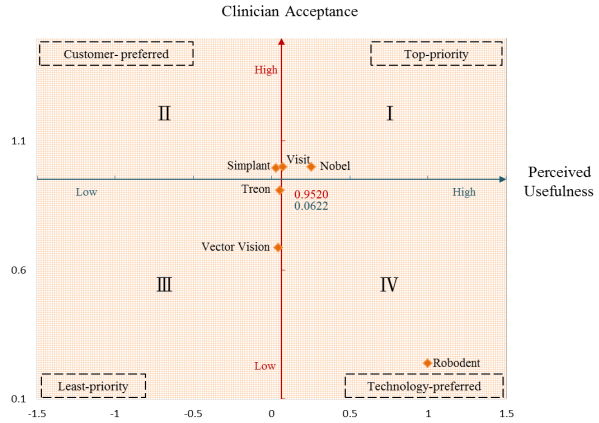

Figure 4. A System Selections Preference Matrix

technological wise but also consider the user's convenience. In this way, users can use the system with more precision and convenience of dental implantation. The causes of the above results are as follows:

- The experimental designs differed. During the experiments regarding accuracy, the deviations in human, model, and cadaver experiments were different. For example, the result from non-living experiments were better than that from clinical experiments. This may be attributable to studies on non-living tissues having a better viewpoint and angle and less interruptions by saliva or patient movement. Thus, the dynamic system has better accuracy that can lower the risks associated with dental implantation.
- The static system obviously has advantages because the arrangement of surgical guides is easy and the facilities are cheap. Besides, the dynamic system requires greater time before and during surgery. In particular, when patients make movements during surgery, general anesthetic is required to prevent these movements from affecting accuracy. This situation is not commonly accepted by doctors or patients during dental implantation.

Moreover, the present study provides system suppliers with the optimal values of intermediate measures, thereby allowing improvements in the overall efficiency of systems according to the suggested values (Table 5).

The two approaches of the computer navigated system have different strengths and weaknesses. Navigation provides surgeons with more freedom and flexibility to adjust the implant position, but it tends to create errors and is less accurate than the navigation system. It requires professional skills; therefore,

surgical knowledge, familiarity, and understanding of the doctor regarding the planned position of the implant influence the execution of system. Further, shaking hands may cause extra deviation. Regarding the static system, its advantages are convenience and ease of use. Therefore, these systems are more commonly

DMU No.	DMU Name	Mean entry	Mean apex	Max entry	Max apex
Static Principle					
1	Nobel	0.7073	0.7868	0.9219	1.0013
2	Simplant	0.6597	1.0314	0.9110	1.5550
Dynamic Principle					
3	Treon	0.8551	0.5701	1.4157	0.6936
4	Robodent	0.3500	0.4700	0.4400	0.5600
5	Visit	0.5805	0.7982	0.7337	1.1046
6	Vector Vision	0.8831	0.6321	0.9110	0.7437

Table 5. Optimal Intermediate Measures

used in studies of computer-guided oral implantology. However, dynamic system is required in certain cases and can be used in a wide range of craniomaxillofacial procedures (e.g., image-guided biopsies, removal of foreign bodies, arthroscopy of the temporomandibular joint, osteotomies, distraction osteogenesis, and tumor surgery) (Widmann and Bale, 2006).

CONCLUSION

The progress of surgery technology has ensured >95% success rate in dental implant surgery. In recent times, dental implantation has taken the place of traditional removable prostheses and has gradually become the dominant treatment due to its stability, greater function, and improved aesthetics after surgery. The dental implant market is increasingly thriving due to an aging population society; the retirement of baby boomers; and the low penetration rate of global dental implant treatments and aesthetic needs. Yet, careful arrangement of implant position prior to surgery, thereby allowing precise implantation, is critical in achieving predictably desirable treatment outcomes. CAD-CAM technology has been developed and quickly improved in this decade to fulfill these requirements.

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International Journal of Management, Economics and Social Sciences
Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017)
2018, Vol. 7(S1), pp.109 – 131.
ISSN 2304 – 1366
http://www.ijmess.com

Application of Intelligence Computing to Optimizing Enzymatic Bioprocessing in Cartilage Hydrolysis

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This study uses the Taguchi orthogonal method and artificial neural network to optimize enzymatic bioprocessing of animal waste cartilage (chicken, mini pig and hog). Specifically, the artificial neural network is used in parallel with the Taguchi orthogonal array process for enzymatic hydrolysis of the cartilage tissue to optimize the best quality of bioactive peptides. The experiment was designed using Taguchi orthogonal array optimal level L25 physical parameters and key media components, namely temperature, pH, enzyme/substrate ratio, substrate concentration, and reaction time. The experimental results were used to train the artificial neural network (ANN) to predict the optimizing enzymatic bioprocessing in animal cartilage hydrolysis. The analysis was performed on a personal computer using NeuroSolutions 6.0 software. The experiment of an enzymatic hydrolysate of three animal cartilages followed the Taguchi orthogonal design, and we discovered that 60±1℃ is the most effective temperature to hydrolyze cartilage. These peptides of molecular size smaller than 10kDa (with 95% values between 10.7kDa and 2.5kDa) were capable of stimulating the porcine chondrocytes to produce glycosaminoglycan (GAG) and type II collagen in vitro. NeuroSolutions 6.0 back-propagation analysis achieved a convergence value of R2=0.9762, indicating that the enzymatic bioprocessing has good performance. Therefore, this study suggests that integrating artificial neural network and Taguchi method when constructing an optimal enzymatic bioprocessing model could significantly increase and improve the quality of final bioactive peptide products. It also suggests that integrating artificial neural network and Taguchi method in the construction of an optimal enzymatic bioprocessing in cartilage hydrolysis could be used as nutraceutical component in bone and joint health

Keywords: Intelligence computing, Taguchi orthogonal array, Neural network, Cartilage hydrolysis, Enzymatic bioprocessing

Cartilage is a flexible connective tissue found in various parts of humans and other animals, including the

Manuscript received May 22, 2017; revised June 17, 2017; accepted July 20, 2017.
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joints between bones, the rib cage, the ears, the nose, the bronchial tubes and the intervertebral discs [1]. It is chemically abundant in collagen, proteoglycans, acidic polysaccharides and water. Conceivably, cartilage can be hydrolyzed to be a potential bioactive material of collagen extraction. In fact, hydrolyzed collagen has been applied in the leather and film industries, pharmaceuticals, cosmetics, biomedical materials and food manufacturing [2]. In particular, some clinical studies report that oral ingestion of hydrolyzed collagen ease the joint pain of osteoarthritis or rheumatoid arthritis, with those having the most severe symptoms showing the most benefit [3, 4 and 5]. Normally, hydrolyzed collagen is isolated from animal (chicken, bovine, porcine, rabbit, duck and antler) cartilages [6, 7 and 8], and fish (skate and shark) cartilages [2, 9 and 10].

A review of methods for extracting hydrolyzed collagen from animal cartilage shows the following. A study conducted in 2005 found that hydrolyzed collagen absorbed small peptides in blood, indicating that the process of hydrolysis involves breaking down the molecular bonds between individual collagen strands using combinations of heat, acids, alkalis, or enzymes, and then reducing collagen proteins of about 300,000 Da into small peptides with an average molecular weight between 2000 and 5000 Da [11]. Specifically, the process is characterized by the following steps: (1) obtaining raw materials from fresh animal cartilage, removing the adipose tissue, cutting adipose tissue into small pieces and soaking a 3% sodium hydroxid for 10-30 hours; (2) using phosphate-buffered saline (abbreviated PBS) to adjust pH value to 3.5-9.5, in proportion to the concentration of animal cartilage particle in g substrate; (3) Adding a plant extract of papain, bromelain or alkaline protease enzymatic protecting agent based on the ratio of animal cartilage particle to g substrate and then adding the composite (enzyme/substrate ratio), incubating with stirring hydrolysis for 4-8 hours; (4) transferring the reaction contents to 45-100℃ water-bath for 8-15 minutes off the enzyme while awaiting completion of incubation; and (5) after cooling to room-temperature, centrifuging the reaction mixture at 3500-5000rpm for 30 minutes at 4℃. Finally, the supernatant fluid and precipitate are separated and freeze-dried [12-17].

Resorting to the above methods [12-17], whether enzymatic hydrolysis, acid hydrolysis or alkaline hydrolysis is used for extracting animal cartilage collagen, the products need to be assured of safety, efficiency, and quality testing before being marketed. Thus, to optimize bioprocessing of cartilage hydrolysis for recovery and production, a combination of various microbial, chemical, enzymatic technologies is

necessary for a chondroprotective effect [2]. It is believed that intelligence computing technology can bring about a significant advancement in product development (as archived pharmaceutical industry) as well as in future business execution and prediction.

-Specific Aims

The primary aim of this study is to use intelligence computing technologies (such as Taguchi orthogonal method and artificial neural network) to optimize enzymatic bioprocessing of animal waste cartilage (chicken sternal cartilage, mini pig laryngeal and tracheal, and hog laryngeal and tracheal) and generate hydrolysis conditions for preparation of hydrolyzate collagen. Specifically, the artificial neural network is used in parallel with the Taguchi orthogonal array process for enzymatic hydrolysis of the cartilage tissue to produce the best yield and quality of bioactive peptides with clinical efficacy for functional ingredients of nutraceuticals. Ultimately, the goal is to develop a valuable and market-potential nutraceutical product for bone and articular joint health care.

A systematic review of the scientific evidence put forth between 1979~2010 [18, 19] shows that a new era in the management of osteoarthritis and nutrition, from nutraceuticals to functional foods, is possible. According to a report published in 2007, nutraceuticals sales were projected to reach $74.7 billion at an AAGR (Average Annual Growth Rate) of 9.9%. In fact, the global market for nutraceuticals is growing day by day and was expected to reach $176.7 billion in 2013 [20]. Particularly, chondroprotective agents including collagen hydrolysate have been used widely as nutraceuticals in osteoarthritis treatments [21]. As such, identification and selection of bioactive factors would be important for engineering mimetic biomaterials/ biological biomaterials to provide not only mechanical support but also biological cues in the induction of a synthesized special cartilage extracellular matrix by chondrocytes. Motivated by such a trend, this study was conducted to advance both academic and industrial interests.

MATERIALS AND METHODS

-Materials

Enzymatic Bioprocessing Materials

This study obtained chicken sternal cartilage from an industrial poultry meat processor (Kai Shing Trading Co., Ltd., Yunlin, Taiwan). The mini pig laryngeal and tracheal and hog laryngeal and tracheal were obtained from PigModel Animal Technology Co., Ltd. The three animal cartilage tissues were stored and frozen before they were processed and prepared as cartilage hydrolysates. Fresh porcine knee joints were purchased from a local meat market and used for isolation of chondrocytes in less than 6hrs. Papain was obtained from Merck (No.107147 Papain 6000USP-U/mg). DMEM/Ham's F12 medium, Fetal Bovine Serum (FBS), Penicillin and Streptomycin were from Invitrogen Corporation, (Carlsbad, CA, USA). Peopidium iodide, Alcian blue, MTT (3-(4, 5-Dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide, a yellow tetrazole), 1,9-dimethyl-methylene blue (DMB), chondroitin sulfate A, calf thymus DNA and Hoechst 33324 and reagent graded chemicals were obtained from Sigma-Aldrich (St. Louis, MO, USA).

Taguchi Orthogonal Working Model

This study obtained the Qualitek-4 from a local agent in Taiwan.

Artificial Neural Network Software

NeuroSolutions 6.0 software was obtained from the local agent that provided the Qualitek-4.

-Methods

Enzymatic Bioprocessing Materials

Optimal levels $L2^5$ of physical parameters and key media components, namely temperature, pH, enzyme/substrate, substrate concentration, and reaction time were determined.

Getting Sarted with Qualitek-4 [31]

Preparation of Cartilage Hydrolysate (see Table 1)

Papain Hydrolysis of Animal Cartilage

Based on the hydrolyzing procedure of avian cartilage used in the study by Vouland *et al.* [14, 15], efforts for the Taguchi orthogonal working model (Qualitek-4 Windows software) were made to reach optimal levels of physical parameters, namely temperature, pH, enzyme/substrate ratio, substrate concentration and duration time [22, 31]. From published information [12-17], this study established the papain hydrolysis of animal cartilage to achieve the following conditions: 60-70±1℃, pH4.5, pH5.5 and pH6.5, enzyme/substrate ratio 0.5%, 0.75%, and 1.0%, substrate concentration 30%, 40% and 50%, duration time 2hrs and 3hrs. At the

end of incubation time, the reaction contents were transferred to 100℃ water bath for 10 minutes. After cooling to room temperature, the reaction mixture was centrifuged at 3500rpm (2200×g) for 30minutes at 4℃. The supernatant fluid and precipitate were separated and freeze-dried. The dried products were stored at room temperature in tide container vials.

Fresh frozen animal cartilage
↓
Thaw in running water
↓
Clean and remove soft tissue, drain dry
↓
Move to boiling water (turn off heating)
↓
Soak for 30-60 minutes (till soft tissue turns whitish)
↓
Cool with tap-water, clean and remove any attached soft tissue (Meat and connective tissue membrane)
↓
Drain, absorb with paper towel
↓
Blend to 5mm particle size

Table 1. Blending Animal Cartilage to 5mm Particle Size

Isolation, Cultivation and Identification of Porcine Articular Chondrocytes

Full-thickness cartilage slices were harvested from porcine knee joints. Then the slices were cut into 1mm^3 pieces and placed in dishes containing 0.2% type I collagenase and transferred to a 37℃ incubator for 16 hours. The chondrocytes liberated were filtered through 10μ m filter to remove undigested cartilage fragments. The isolated cells were washed and re-suspended in completed medium (DMEM/Ham’ s F12 medium containing 10% FBS and 100 U/ml Penicillin and 100 μ g/mL Streptomycin) and their viability was determined using trypan blue dye exclusion.

Cells were expanded by monolayer culture in completed medium. At 80 to 90% confluences, the cells were trypsinized and re-suspended in completed medium at a concentration of 1×105 cells/ ml. The 5ml cell suspension was placed into culture flask and at 37℃ in a humidified 5% CO2 incubator. This was the P1 passage of the primary culture of chondrocytes.

Cell Morphology

A cell climbing sheet of P3 chondrocytes was washed with PBS, fixed with 4% paraformaldehyde for 15 minutes, stained with 1% alcian blue for 30 minutes and washed with ddH2O. Cell morphology was observed using a microscope and photography was taken at a magnification of 100× for further examination.

Evaluation of Cell Cytotoxicity and Proliferative Effects

The cartilage hydrolysate on the chondrocyte cultures by MTT assay. The chondrocytes were cultured in completed medium and cultured overnight. For cytotoxicity assay, chondrocytes were treated with cartilage hydrolysate in serial dilutions of concentrations 200mg/ ml to 0.0002mg/ml for 24hours. For proliferation analysis, the cells were treated with various concentrations of cartilage hydrolysate (2mg/ml, 0. 2mg/ml and 0.02mg/ml) for 2, 7 and 14 days. After treatment, 10μ M MTT (5mg/ml in PBS) were added to each culture well, and the cultures were incubated at 37℃ for 4hours. The purple-blue MTT formazan precipitate was dissolved in 100μ l DMSO and cells were shaken for 5 minutes. Absorbance was measured at 570 nm using ELISA reader.

Biochemical Analysis

The P3 chondrocyte culture were treated with cartilage hydrolysate and assessed for Glycosaminoglycans (GAG) type II collagen and DNA content. Briefly, cells were washed with PBS and digested by incubation for 16 hours at 60℃ in papain digest buffer. The measurement of total sulphated GAG in the chondrocyte culture was performed using the 1,9-dimethyl-methylene blue (DMB) dye method. Chondrotin sulfate A from bone cartilage was diluted with distilled water to prepare a standard curve (0 to 80μ g/ml). A 96-well plate was used and 40 μ l of GAG standards or the papain-digested samples were piped into each well, then 250 μ l of DMB solution was added to each well. Absorbance at 525 nm was determined using a spectrophotometer (Biorad Plate-Reader, BioRad Laboratories, Hemel Hempstead, UK) at a wavelength of 595 nm.

Determination of DNA Content Using Hoechst 33324 Fluoresce-Metric Assay

DNA from calf thymus was used to prepare a standard dilution curve ranging from 0 to 2.5μ g/ml. 100μ l aliquots of standards or sample and Hoechst 33324 (1μ g/ml) were added into a 96-well plate. The samples were read on a fluorimeter with a 365nm excitation filter emission set at 460nm, and the GAGs were normalized to the DNA content.

Quantification of Type II Collagen

Porcine type II collagen was determined by means of the Collagen type II ELISA kit (MD Bioscience, Inc, Switzerland). To solubilize the newly synthesized collagen, the cell culture medium was removed and pepsin solution was added to the cell layer and digested the collagen at 2-8℃overnight. Subsequently, TXB (0.1M Tris, 0.2M NaCl, 5mM CaCl2, pH 7.8-8.0) was added to stop the reaction. To monomerize the remaining polymeric collagen, pancreas elastase solution was added to the samples and incubated at 2-8℃ overnight. After centrifugation (10,000rpm for 5 minutes), the supernatant was assayed for type II collagen by ELISA.

Molecular Size Distribution

The cartilage hydrolysate was characterized by HPLC analysis using an LC system consisting of a Waters model 600E solvent delivery system (a Waters model 996 Photodiode Array Detector and a Waters 717 Plus auto-sampler using a 200 μ l sample loop). Empower software was used to control the system and to perform the data analysis. The size exclusion experiments were performed at room temperature using a 10× 300nm Superdex™ peptide column (GE Healthcare) eluted at 0.4ml/min with 10mM phosphate buffer, pH7.4 and containing 0.15M NaCl as the mobile phase. Sample volumes of 40μ l were used. The molecular mass of the peptides was estimated with molecular weight markers of range 2,512-16,949 (Amersham Biosciences, Code No. 80-1129-83). Above data obtained were analyzed using SPSS software. Results are expressed as mean ± SD.

Application Supervised ANN for Optimizing Enzymatic Bioprocessing

NeuroSolutions is a neural network development environment by NeuroDimension, Inc. It combines a modular, icon-based (component-based) network design interface with an implementation of advanced learning procedures, such as conjugate gradients, Levenberg-Marquardt and backpropagation through time. The software is used to design, train and deploy neural network (supervised learning and unsupervised learning) models to perform a wide variety of tasks, such as data mining, classification, function approximation, multivariate regression and time-series prediction.

care service training, service redesign, and Standard Operating Procedures (SOP). However, these actions are still insufficient to close the gaps between the provided services and seniors' needs (Chen et al., 2005,

2006; Chen *et al.*, 2004; Chuang, 2007; Keleher *et al.*, 2007).

RESULTS

Biological and Enzymatically Experimental Results

-Hydrolysis of Three Animal Cartilages

This biochemical structure of cartilage has a high water content of 60-97%. Our hydrolyzed rate was in good agreement with published results. The high water content was also in the range of reported data [12-15].

-Molecular Size Distribution

The molecular weight distribution of the cartilage papain hydrolyzed product is shown in Figure 1 (SEC-HPLC chromatograms). Based on the area under cover the molecular weight distribution, more than 97% of cartilage hydrolysate' s molecular weight was less than 10.7kDa. We also have observed that all of the molecular weight of cartilage lysate was less than Ribonuclease A (Mwt. 13700) as analyzed by Superdex 75 (data not shown)]. Additionally, 58% of cartilage hydrolysate has a molecular weight of between 10.7 and 6.2kDa, while 40% of cartilage lysate has a molecular weight of less than 6.2kDa.

Figure 2 shows the heat-hydrolyzed (not enzyme-hydrolyzed) cartilage hydrolysate. More than 83% of molecules in the heat-hydrolyzed cartilage product appeared to be above the upper separation limit of SEC-HPLC (before retention time of 20 minutes). The result indicated that the majority of heat-hydrolyzed cartilage products still retained their high molecular weight structures. As shown in Figure 3, about 14% of small molecular weight product appeared after a retention time of 42 minutes. Its identity and properties require further study.

-Cytotoxic and Mitogenic Effects of Cartilage Hydrolysate

Figure 4 shows the cartilage papain-hydrolysate is not cytotoxic to the primary porcine chondrocytes at a concentration below 20mg/ml and lower. At a concentration of 200mg/ml, it displayed a significantly lowered viability that could be due to other physical properties or its having very weak toxicity.

Figure 5 shows the cartilage papain-hydrolysate had no mitogenic effects on porcine chondrocyte culture.

Cartilage papain-hydrolysate stimulating GAG expression

Figure 6 shows the cartilage papain-hydrolysate induced GAG production by the primary porcine chondrocyte cultures at day 14. Figure 7 shows the treatment of cultured chondrocytes with 0.2 and 0.02mg/ml sample induced a marked increase in type II collagen synthesis. At the end of the culture period (18 days), type II collagen synthesis was almost 11.9-fold higher in sample stimulated cultures in comparison with the control cells.

Our cartilage hydrolysate was presented in molecular size smaller than 10kDa (Fig.1, 2 and 3) with the capability of stimulating chondrocytes to express GAG (Fig. 6) and type II collagen (Fig. 7) , thus fulfilling the requirement of being dietary peptides. Dietary peptides are known to have biological importance beyond their nutritive value of intact protein and individual amino acids [12-17, 46]. It is well recognized that apart from their basic nutritional role many food proteins contain encrypted within their primary structures peptide sequences capable of modulating specific physiological functions [43-46]. In this study, the cartilage hydrolysate was prepared by papain hydrolysis and resulted in various sizes of a fragment including peptides and saccharide-aggregates, with stimulating/enhancing of the anabolic activity of chondrocyte. This bioactive property was similar to reports of bioactive peptides having been found in enzymatic protein hydrolysates [12-17].

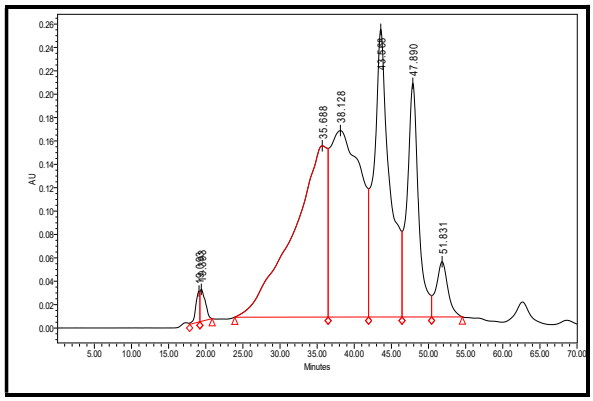

Figure 1. HPLC Chromatogram of Cartilage Hydrolysate Products: Cartilage Hydrolysate Product was Separated by the Superdex^{TM} Column

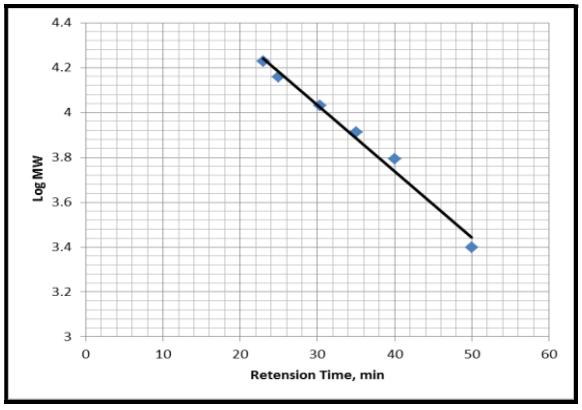

Figure 2. HPLC Chromatogram of Amersham Standards (80-1129-83)

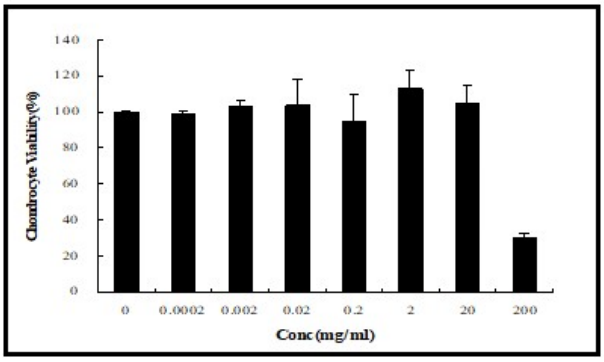

Figure 3. HPLC Chromatogram of Heat-Hydrolyzed Cartilage Products

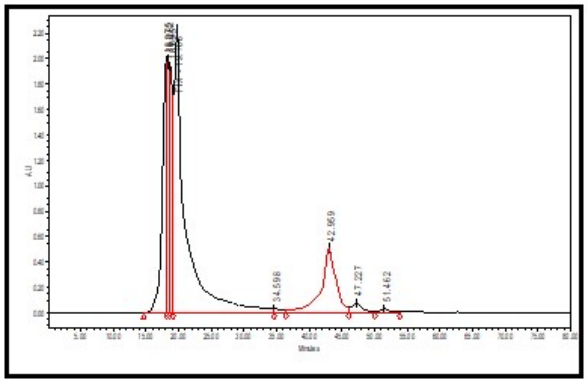

Figure 4. Cytotoxicity Evaluation of the Sample on Chondrocytes. Chondrocytes were treated with various concentrations of the sample for 24hrs. Chondrocytes Cytotoxicity was determined by MTT assay

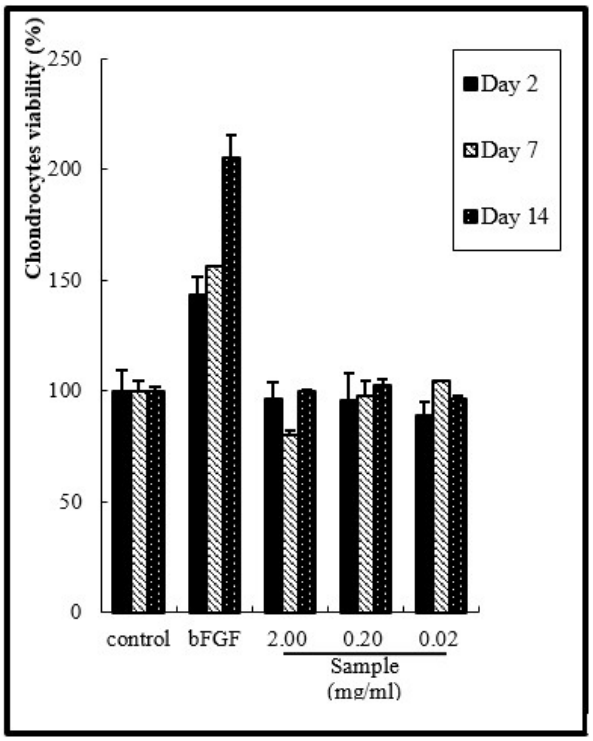

Figure 5. Effects of the Sample on Chondrocytes Proliferation Chondrocytes were treated with various concentrations of the sample for 2, 7 and 14 days. Chondrocytes viability was determined by MTT assay

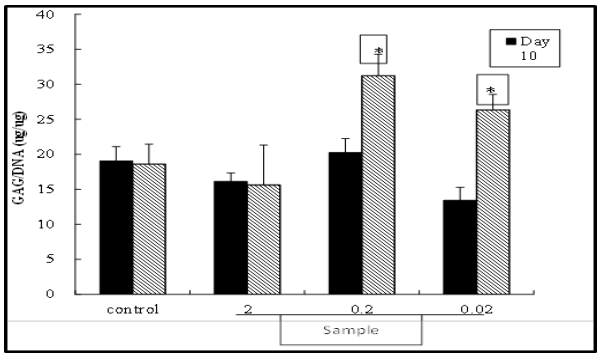

Figure 6. Effects of the Sample on GAG Content of Chondrocytes. Chondrocytes were treated with various concentrations of the sample for 10 and 14 days. GAG and DNA content were determined by DMMA assay and Hoechst 33324. *p< 0.05 compared with untreated controls

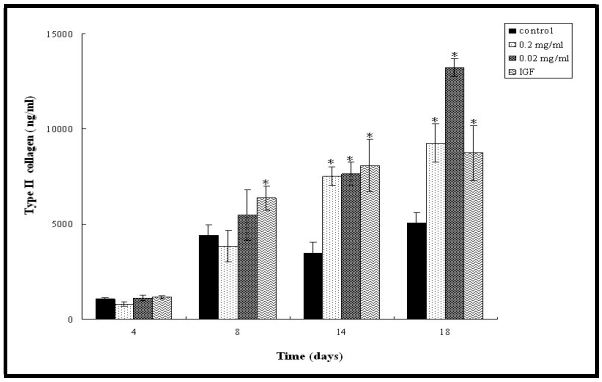

Figure 7. Effects of the Sample on Type II Collagen Expression of Chondrocytes. Chondrocytes were treated with three concentrations of cartilage hydrolysate product for indicated durations. *p< 0.05 compared with untreated controls

Neural Network Assessment and Statistical Analysis

NeuroSolutions 6.0 neural network software (Back-propagation Network) was into the production process to parallel the orthogonal array in the construction of the prediction model for the 89 experiments. The biological enzymatically results (target value: supernatant recovery rate) demonstrated good consistency in the sample duplications and experimental groups, and the artificial intelligence computing convergence value (R2=0.9762) indicated this enzymatic bioprocessing had good performance (Figure 8-24).

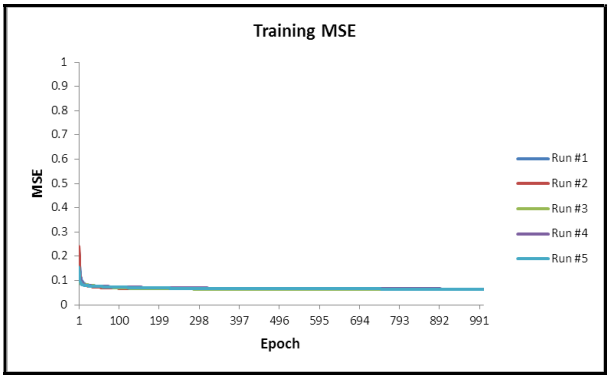

Figure 8. Training MSE: Papain Hydrolysis of Chicken Sternal Cartilage

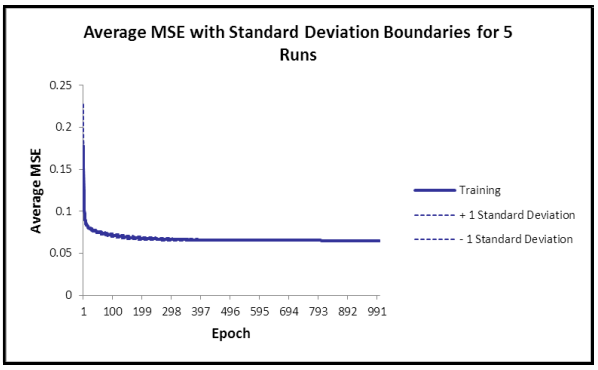

Figure 9. Training Report: Papain Hydrolysis of Chicken Sternal Cartilage

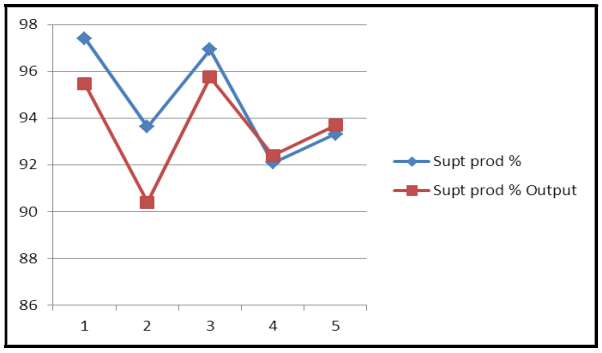

Figure10. Testing Trend: Papain Hydrolysis of Chicken Sternal Cartilage

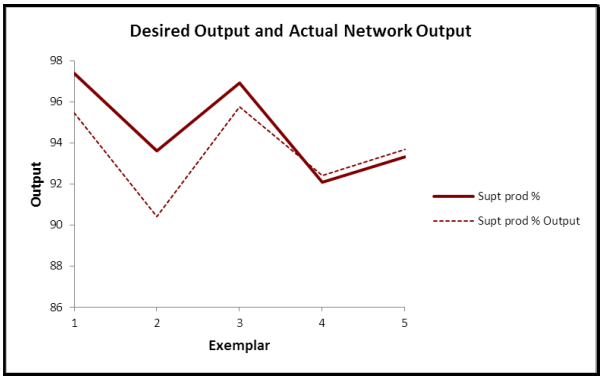

Figure11. Testing Trend: Papain Hydrolysis of Chicken Sternal Cartilage

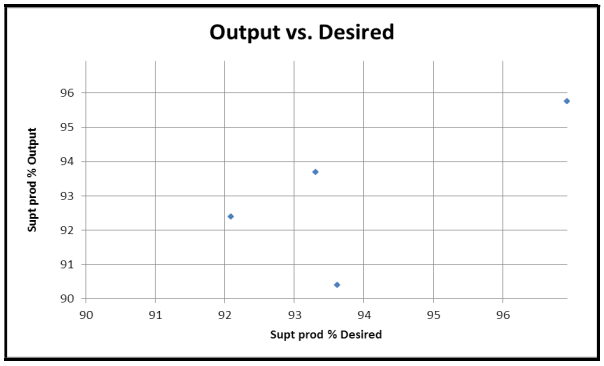

Figure 12. Testing Report: Papain Hydrolysis of Chicken Sternal Cartilage

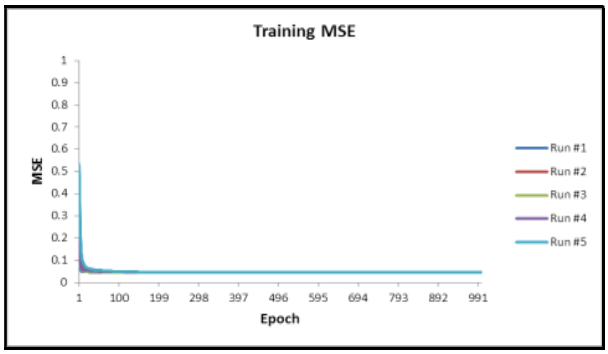

Figure 13. Training MSE: Papain Hydrolysis of Mini Pig Laryngeal and Tracheal Cartilage

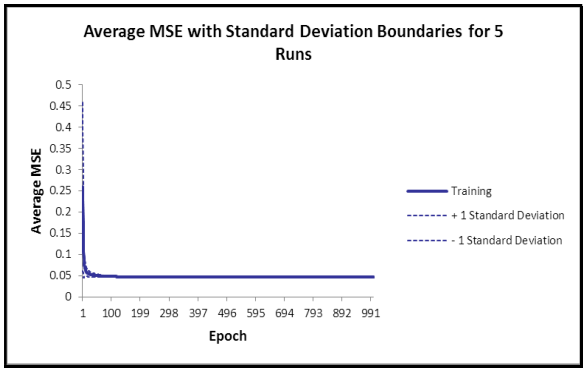

Figure 14. Training Report: Papain Hydrolysis of Mini Pig Laryngeal and Tracheal Cartilage.

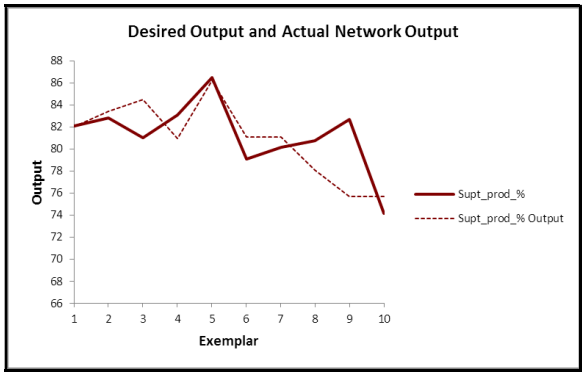

Figure 15. Testing Trend: Papain Hydrolysis of Mini Pig Laryngeal and Tracheal Cartilage

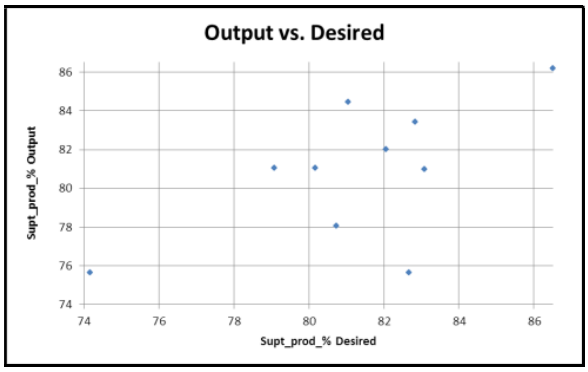

Figure 16. Testing Report: Papain Hydrolysis of Mini Pig Laryngeal and Tracheal Cartilage

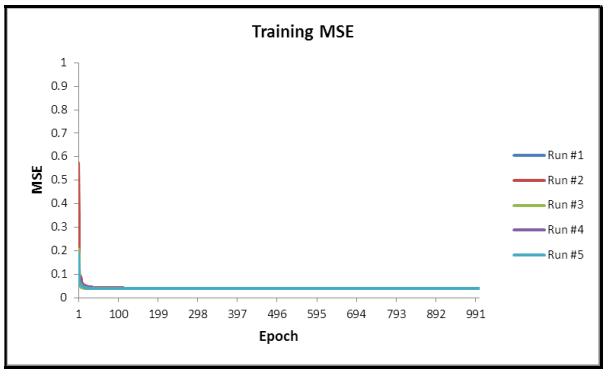

Figure 17. Training MSE: Papain Hydrolysis of Hog Laryngeal and Tracheal Cartilage

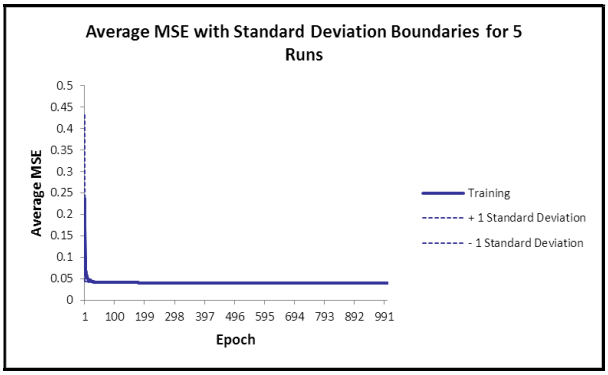

Figure 18. Training Report: Papain Hydrolysis of Hog Laryngeal and Tracheal Cartilage

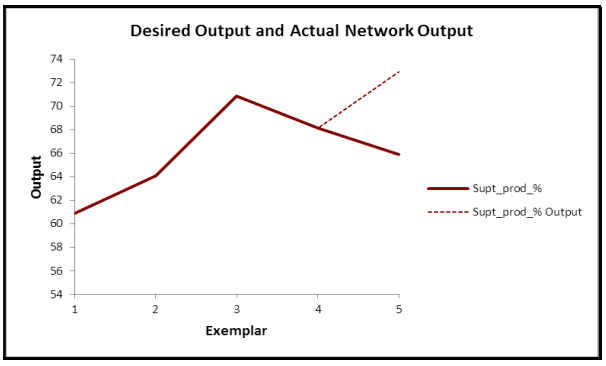

Figure 19. Testing Trend: Papain Hydrolysis of Hog Laryngeal and Tracheal Cartilage

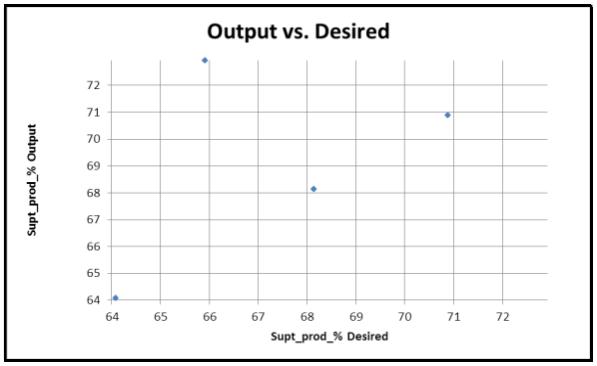

Figure 20. Testing Report: Papain Hydrolysis of Hog Laryngeal and Tracheal Cartilage

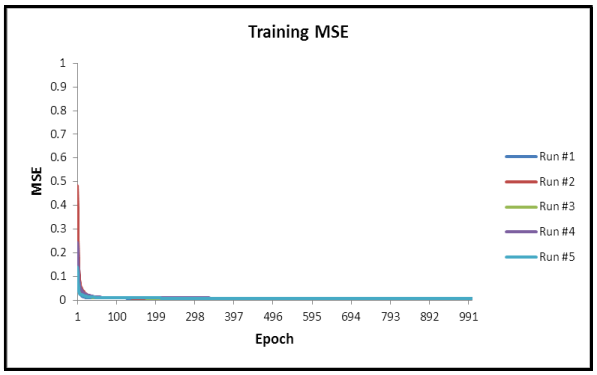

Figure 21. Training MSE: Papain Hydrolysis of Mixture of Three Animal Cartilages

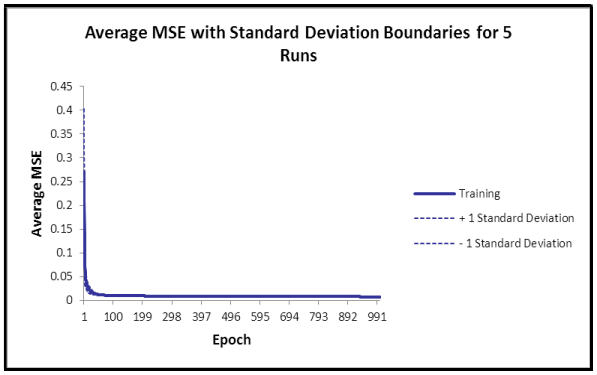

Figure 22. Training Report: Papain Hydrolysis of Mixture of Three Animal Cartilages

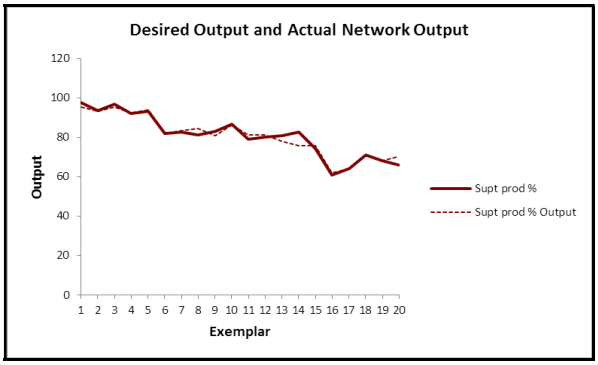

Figure 23. Testing Trend: Papain Hydrolysis of Mixture of Three Animal Cartilages

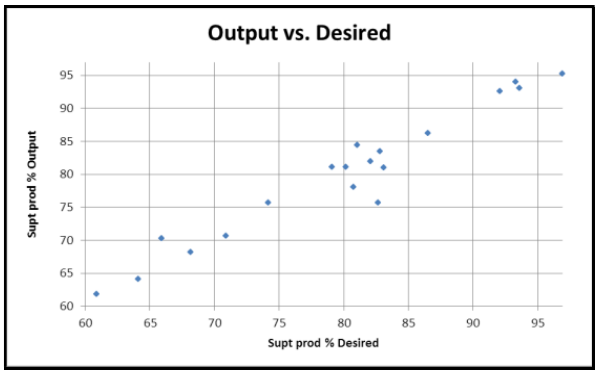

Figure 24. Testing Report: Papain Hydrolysis of Mixture of Three Animal Cartilages

DISCUSSION

Neural Network Performance

NeuroSolutions 6.0 neural network software (Back-propagation Network) was incorporated into the production process to parallel the Taguchi orthogonal array in the construction of the prediction model for the 89 experiments. The biological enzymatically results were 92.09-93.03% (target value: supernatant recovery rate) appeared to have good consistency in the sample duplications and experimental groups, and the artificial intelligence computing convergence value was R2=0.9762, indicating this enzymatic bioprocessing had good performance. However, the analysis indicated the papain enzyme/substrate ratio as the major impact factor in this enzymatic hydrolysis to produce high yields of final bioactive peptide products (Figure 8-24).

Optimizing Enzymatic Bioprocessing

In 1999, collagen hydrolysate (prepared from gelatin) was shown to be absorbed in its high-molecular weight by containing peptides of 2.5kDa to 15kDa [13-18]. Recently, a report showed hydrolyzed chicken sternal cartilage extract of novel low molecular weight (from 0.05kDa to 10kDa with average 5.5 kDa), indicating an improved osteoarthritis-related system in a Randomized, Double-Blind, Placebo-Controlled Trail [13-16]. The molecular size of our cartilage hydrolysate was smaller than 10.7 kDa, which is comparable to the published result [14-17].

Significantly, this study provides a simple, easy and economical way of preparing 10 to 100 grams of cartilage hydrolysate required for further investigations.

Hydrolyzed chicken cartilage powder is a natural source of BSE free type II collagen and chondroitin sulfate. Extensive research has shown the benefit of these two substances for both healthy and unhealthy joints. Furthermore, ongoing research and studies continue to uncover their mechanisms of action and to strengthen the evidence of their efficiency [14-17].

-Hydrolyzed collagen type II having an average molecular weight

Animal cartilage-derived material comprising hydrolyzed collagen type II, said hydrolyzed collagen type II having an average molecular weight of between about 1,500 and 2,500 Daltons [14-17].

-Comprising hydrolyzed collagen type II having an average molecular weight

A method for treating an individual with a connective tissue disorder, comprising orally administering to said individual an effective daily amount of chicken sternal cartilage-derived material comprising hydrolyzed collagen type II having an average molecular weight of between 1,500 and 2,500 Daltons [14-17].

-Intelligence computing technology can optimize enzymatic bioprocessing in animal waste cartilage

It is believed that intelligence computing technology can bring about significant advancement in product development (as archived pharmaceutical industrial) as well as in future **business** execution and prediction (such as Taguchi orthogonal method and artificial neural network) by optimizing enzymatic bioprocessing in animal waste cartilage (chicken sternal cartilage, mini pig laryngeal and tracheal, and hog laryngeal and tracheal) and generating hydrolysis conditions for preparation of hydrolyzate collagen. Specifically, the artificial neural network is used in parallel with the Taguchi orthogonal array process for enzymatic hydrolysis of the cartilage tissue to produce the best yield and quality of bioactive peptides with clinical efficacy for functional ingredients of nutraceuticals.

CONCLUSION

This study comprises two parts: one is the biological experiment of papain hydrolysis of animal (chicken, mini pig and hog pig) cartilage and the other is the neural network computing and analysis in an attempt to locate a predicting model for the formulation of a better enzymatical production procedure for bioactive-functional peptides.

The enzymatic hydrolysate of three animal cartilages was processed following the Taguchi orthogonal design. It was discovered that a hydrolyzing temperature of 60±1℃ is the most effective to hydrolyze the cartilage. The chicken sternal cartilage could be hydrolyzed by papain to produce a molecular size smaller than 10kDa (with 95% in 10.7kDa and 2.5kDa). These peptides were demonstrated to be capable of stimulating the porcine chondrocytes to produce glycosaminoglycan (GAG) and type II collagen *in vitro*. Thus, it is concluded that animal cartilage papain-hydrolysate contain bioactive peptides or factors and could be a good agent for chondrogenesis and regeneration of cartilage tissue. The product of this research can be applied in nutraceuticals since it has been granted " GRAS" status by the US FDA.

In the second part of this study, through NeuroSolutions 6.0 analysis, it is concluded that the good conversion value (R2=0.9762) is an indication that based on this study experiments can perform neural network analysis. The training MSE-papain hydrolysis of a mixture of three animal cartilages also indicated the best final MSE =0.00779.

However, the testing input/output data: papain hydrolysis of a mixture of three animal cartilages indicate the papain enzyme/substrate ratio to be the major impact factor in this enzymatic hydrolysis to produce high yields of the final bioactive peptide products.

Indeed, the chicken sternal cartilage can be efficiently hydrolyzed by papain to produce a molecular weight smaller than 10kDa with 95% in 10.7kDa, 6kDa and 2.5kDa fragments or peptide with biological activity capable of stimulating the primary porcine chondrocyte to express GAG and type II collagen in culture. The cartilage hydrolysate could be used as ingredients in food supplements and nutraceuticals. Also importantly, it should be considered as safe as collagen hydrolysate which has been granted GRAS status by the US FDA in 2003. Finally, the cartilage hydrolysate could also be a biomimetic biomaterial for bone and connective tissue regeneration studies.

FUTURE DIRECTIONS

This study results suggest that intelligence computing manipulation of bioprocessing engineering could improve the goods of final bioactive peptide products. Nevertheless, waste animal cartilages can indeed become the green resources for biotechnology to convert low valued by-products of the meat industry for eventual use as functional food ingredients and nutraceutical components for bone and joint health.

Bioprocess engineering is a conglomerate of mathematics, biology and industrial design. It also consists of various biotechnological processes used in industries for large-scale production of biological products for optimization of yield and quality [48]. It is believed that the intelligence computing technology can bring about significant advancements in product development (as archived pharmaceutical industrial) as well as in future business execution and prediction.

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ACKNOWLEDGMENT

The author wishes to convey her sincere thanks to Dr. Ling-Hui Hsu and the Industrial Technology Research Institute, Biomedical Technology and Device Research Laboratories. Special thanks too to Dr. Chao-Ying Kuo, Dr. Pei-Yi Tsai and their colleagues for assisting this research.

International Journal of Management, Economics and Social Sciences
Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017)
2018, Vol. 7(S1), pp.132 – 141.
ISSN 2304 – 1366
http://www.ijmess.com

A Comparative Analysis of Data Mining Techniques for Prediction of Postprandial Blood Glucose: A Cohort Study

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The use of advanced predictive techniques and reasoning models has greatly assisted clinicians in improving the diagnosis, prognosis, and treatment of diabetes. Although numerous studies have focused on the relationship between abnormal blood glucose levels and diabetes, few have focused on the risk forecasting of postprandial blood glucose levels in patients with diabetes. This work aimed to develop a model for the prediction of postprandial blood glucose levels to screen for undiagnosed diabetes cases in a cohort study. The performance of the proposed model was then compared with those of five other data-mining techniques: random forest (RF), support vector machine (SVM), C5.0, multilayer perceptron (MLP), and logistic regression (LR). The data of 1,438 patients who were admitted to Landseed Hospital, Northern Taiwan, over the period of 2006 and 2013 were collected and used to evaluate the performances of the data-mining techniques. Compared with the 4.5, SVM, MLP, and LR models, the RF model had the best prediction capability for postprandial blood glucose levels in terms of the overall correct classification rate. The results of this study underscore the importance of identifying the preclinical symptoms of abnormal blood glucose levels. The proposed model provides precise reasoning and prediction and can be used to help physicians improve the diagnosis, prognosis, and treatment of patients with diabetes.

Keywords: Data mining techniques, random forest, support vector machine, multilayer perceptron, logistic regression

The global prevalence of diabetes mellitus, commonly referred to as diabetes, has drastically increased (Liu et al., 2017). Consequently, dialysis treatment for diabetic nephropathy has become a large burden on the national health insurance of Taiwan. The early diagnosis of the risk factors related to changes in postprandial blood glucose levels could help prevent or delay diabetic nephropathy. Moreover, early diagnosis may

Manuscript received May 24, 2017; revised June 20, 2017; accepted July 20, 2017.
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improve the outcomes of patients with diabetes, and the regular screening of blood glucose levels and blood pressure can decrease the incidence of diabetes. Screening for undiagnosed diabetes through blood sampling, however, is prohibitive because of the high costs and invasiveness of the technique. Accurate and precise reasoning and prediction models may greatly help physicians improve the diagnosis, prognosis, and treatment of diabetes. Several studies have been conducted to clarify the response of glucose levels in diabetic patients to various stimuli. Several factors affect the postprandial levels of blood glucose. These factors include age, weight, waist girth, white blood red blood cell counts, and globulin, high-density lipoprotein, and urine red blood cell concentrations.

Data-mining techniques have been widely used to predict blood glucose levels. The use of data-mining techniques to construct prediction models for blood glucose levels does not require strong model assumptions and can capture delicate underlying patterns and relationships in empirical data, hence providing promising results for the prediction of blood glucose levels. Although data-mining techniques have been utilized in numerous studies to predict fasting blood glucose and/or postprandial blood glucose levels, few studies have attempted to utilize data-mining techniques to predict or classify postprandial blood glucose as normal or abnormal. Moreover, most existing studies on blood glucose levels in diabetic patients are based on a continuous glucose monitoring system, a device that is installed on the patient for measuring the patient' s blood glucose over specific intervals. To the best of our knowledge, no study has utilized data-mining for the prediction of postprandial blood glucose levels in a cohort study. Therefore, a model for the prediction of postprandial blood glucose levels was proposed and designed in this study. The predictive performance of the proposed model was compared with those of five data-mining techniques.

The five data-mining methods used in this study are random forest (RF), support vector machine (SVM), C5.0, multilayer perceptron (MLP), and logistic regression (LR). RF is an ensemble learning method that grows multiple random tree classifications to generate an overall classification. SVM is based on statistical learning theory and is derived from the structural risk minimization principle for estimating a hyperplane for classification. C4.5 is a non-parametric and fast classification technique that adopts a greedy approach and uses a top-down recursive divide-and-conquer strategy to construct a decision tree. MLP is a neural network

commonly used to solve classification problems and is trained with a backpropagation algorithm. MLP also utilizes a supervised learning technique to transform sets of input data into a desired output. LR is a widely used statistical modeling technique that is a special case of the linear regression model. The major advantage of this approach is that it can produce a simple probabilistic formula of classification. These five data-mining techniques have been used to predict blood glucose levels. However, to the best of our knowledge, these five models have not been used to predict postprandial blood glucose levels in a cohort study.

Tresp et al. (1999) utilized recurrent neural networks and time-series convolution neural networks to predict the blood glucose levels of patients with diabetes. The recurrent neural network combined with the linear error model exhibited excellent performance and outperformed the compartment and time-series convolution neural-network models. Wang et al. (2016) used an improved grey (1, 1) model to predict the postprandial blood glucose levels of patients with type 2 diabetes using limited data. The improved grey model outperformed the autoregressive (AR) model in the prediction of blood glucose levels. Wang and An (2014) applied a least-squares-based AR model to predict blood glucose levels. The model accurately illustrated the changes in blood glucose levels to provide an early warning for the occurrence of low blood glucose. García-Jaramillo et al. (2013) adopted and compared the performance of three interval models in predicting the postprandial blood glucose levels of patients with type 1 diabetes under the conditions of uncertainty and intra-patient variability. The rest of this paper is organized as follows. A brief review of related works is presented in Section 2. RF, SVM, C4.5, MLP, and LR are introduced in Section 3. The experimental results are provided in Section 4, and the conclusion is provided in Section 5.

METHODOLOGY

-Random Forest

Random forest (RF) is a supervised machine learning algorithm which combines classification method based on the un-weighted majority of class votes (Breiman, 2001). In a RF, first, multiple random samples of variables are selected as the training dataset using the bagging procedure. The bagging procedure means

random sampling with replacement which is a meta-algorithm can be used to reduce variance and aids to elude over-fitting synchronously. Then, the tree-type classifiers corresponding to selected samples are constructed in the data training process. A large number tree makes RF from the selected samples. Finally, all classification trees are combined and final classification results are obtained by voting on each class and then choosing the winner class in terms of the number of votes to it. The RF performance measure by a metric called out of bag error calculated as the average of the rate of error in each weak learner. In RF, each individual tree is explored in a particular way. First, given a set of training data N, n random samples with repetition (Bootstrap) are taken as training set by using bagging procedure. Then, for each node of the tree, M input variables are determined, and m variables (<<M) are selected for each node. The most important variable randomly chosen is used as a node. The value of m remains constant. Finally, each tree is developed to its maximum expansion. Please refer to Breiman (2001) for more detail information of RF.

-Support Vector Machine

The basic idea of SVM initially, linearly or non-linearly, map the input vectors into a higher dimensional feature space. Then, SVM seeks an optimized hyperplane to separate two classes in the feature space. A description of SVM algorithm is follows. Let $\{(\mathbf{x}_i, y_i)\}_{i=1}^{N}$, $\mathbf{x}_i \in R^d$, $y_i \in \{-1, 1\}$ is the training set with input vectors and labels. Where, N is the number of sample observations and d is the dimension of each observation, y_i is known target. SVM is to seek the hyperplane $\mathbf{w} \cdot \mathbf{x}_i + b = 0$, where w is the vector of hyperplane and b is a bias term, to separate the data from two classes with maximal margin width $2/\|\mathbf{w}\|^2$, and the all points under the boundary is named support vector. For optimal the hyperplane, SVM is to solve the following optimization problem (Vapnik 2000).

$$\text{Min} \quad \Phi(\mathbf{x}) = \frac{1}{2}\|\mathbf{w}\|^2 \qquad (1)$$

$$\text{S.t.} \quad y_i(\mathbf{w}^T \mathbf{x}_i + b) \geq 1, i = 1, 2, ..., N$$

As it is hard to solve eq.(1), it is transformed to be dual problem by using Lagrange method. The value of α in the Lagrange method must be non-negative real coefficients. The eq. (1) is transformed into the following constrained form,

$$\text{Max} \quad \Phi(\mathbf{w}, b, \xi, \alpha, \beta) = \sum_{i=1}^{N} \alpha_i - \frac{1}{2} \sum_{i=1, j=1}^{N} \alpha_i \alpha_j y_i y_j \mathbf{x}_i{}^T \mathbf{x}_j \quad (2)$$

$$\text{S.t.} \sum_{j=1}^{N} \alpha_j y_j = 0, \quad 0 \le \alpha_i \le C, i = 1, 2, ..., N$$

In eq. (2), C is the penalty factor and viewed as a tuning parameter which can be used to control the trade-off between maximizing the margin and the classification error. In general, it could not find the linear separate hyperplane in all application data. In the non-linear data, it must transform the original data to higher dimension of linear separate is the best solution. The higher dimension is called feature space, it improve the data separated by classification. The common used kernel function is radial basis function (RBF). It is applied in this study. For more details about SVM, please refer to Vapnik (2000).

-C 4.5

C4.5 classifier is a process for the classification and retrieves useful information in the form of a decision tree. The algorithm adopts a greedy approach in which the decision trees are constructed in a top-down recursive divide and conquer manner on the basis of a training set (Quinlan 1993). C4.5 builds decision trees from a set of training data based on the concept of information entropy. The training data is a set of already classified samples. Each sample is a vector including attributes or features. The training data is augmented with a vector representing the class that each sample belongs to. Each attribute of the data can be used to make a decision. C4.5 examines the normalized information gain that results from choosing an attribute for splitting the data. The attribute with the highest normalized information gain is the one used to make the decision. The algorithm then recurs on the smaller sub-lists. For more details about C4.5, please refer to (Larose 2005).

-Multilayer Perceptron

Multilayer Perceptron (MLP) is gained their popularity due to it is a simple architecture but a powerful problem-solving ability. Back propagation is a general supervised method for iteratively calculating the weights and biases of the MLP. This type of model is termed BPN. BPN uses a steepest descent technique with learning and momentum terms. A BPN topology consists of a number of nodes (neurons) connected by links and consists of three layers: input layer, hidden layer(s) and output layer. The nodes in the input layer

receive input signals from an external source and the nodes in the output layer provide the target output signals. Any layers between input and output layers are called hidden layers. Since one hidden layer network is sufficient to model any complex system with desired accuracy the designed BPN model in this study will have only one hidden layer. A three-layer BPN is used in this study. In a BPN topology, each layer comprises several neurons that are interconnected by sets of weights. The neurons obtain inputs from initial inputs or interconnections and generated outputs using a nonlinear transfer function. BPN uses gradient steepest descent training algorithm to minimize error and adjusts interconnection weights. For the gradient descent algorithm, the step size, called the learning rate, must be specified first. The learning rate is crucial for BPN since smaller learning rates tend to slow down the learning process before convergence while larger ones may cause network oscillation and unable to converge. Please refer Haykin (1999) for more details about MLP.

-Logistic Regression

LR is similar to a linear regression model but is suited to models where the dependent variable is dichotomous. A logistic regression model specifies that an appropriate function of the fitted probability of the event is a linear function of the observed values of the available explanatory variables. In producing the LR equation, the maximum-likelihood ratio was used to determine the statistical significance of the variables. LR is useful for situations in which can be able to predict the presence or absence of a characteristic or outcome based on values of set of predictor variables. LR model for p independent variables can be written as

$$H(Y=1)=\frac{1}{1+e^{-(\beta_0+\beta_1x_1+\beta_2x_2+\cdots+\beta_px_p)}} \qquad (3)$$

where $P(Y=1)$ is probability of presence. And $\beta_0,\beta_1,\beta_2,\cdots,\beta_p$ are regression coefficients. There is a linear model hidden within the logistic regression model. The natural logarithm of the ratio of $P(Y=1)$ to $1-P(Y=1)$ gives a linear model in X_i:

$$g(x)=ln\left(\frac{P(Y=1)}{1-P(Y-1)}\right)=\beta_0+\beta_1x_1+\beta_2x_2+\cdots+\beta_px_p \qquad (4)$$

The $g(x)$, has many of the desirable properties of a linear regression model. The independent variables can be a combination of continuous and categorical variables.For more details about logistic regression, please refer to Hosmer et al. (2013).

Data Collection

We collected data from LandSeed Hospital for 2006-2013. After excluding some follow-up records (e.g., records for patients age<18), we obtained records for patients who visited the hospital on three separate occasions over the period of 2006 and 2013 for two consecutive years. The patients had normal postprandial blood glucose levels at the first visit and may have abnormal postprandial blood glucose levels at the third visit. The data included 1438 clinical follow-up records. Of these records, 438 patients reported abnormal postprandial blood glucose at the third visit. Previous studies have studied the incidence and risk factors associated with diabetes. In this study, each subject in the dataset contained 29 predictor variables, as shown in Table 1, and the response variable is whether the postprandial level of blood glucose is normal or not. The performances of the five data-mining methods were evaluated using the 10-fold cross-validation method. The data-mining software WEKA, which was developed by Frank et al. (2016), was utilized to develop the RF, C4.5, SVM, MLP, and LR models with default settings for each algorithm.

RESULTS

Sensitivity and specificity are the two important measures in medical/healthcare classification. Sensitivity (also called the true-positive rate) is a measure of the proportion of positives that are correctly identified, and specificity (also called the true-negative rate) is a measure of the proportion of negatives that are correctly identified. The correct classification rate (CCR), sensitivity, and sensitivity were used as the three indexes for judging the performance of the five classification methods.

The classification results for postprandial blood glucose levels (the confusion matrix) predicted by the RF model are summarized in Table 1. From the results presented in Table 1, we can observe that the overall CCR is 82.68%. That is, {1-1} is 923 (CCR of 92.30%) and {2-2} is 266 (CCR of 60.73%). {1-1} represents sensitivity and indicates that a class 1 subject, which is a subject with normal postprandial blood glucose levels, is correctly classified into class 1. {2-2} represents specificity and indicates that a class 2 subject, which is a subject with abnormal postprandial blood glucose levels, is correctly classified into class 2.

Tables 2–5 show the classification results of C4.5, SVM, MLP, and LR, respectively. Table 2 shows that

the overall CCR of the C4.5 method is 76.56% with a sensitivity of 85.90% and specificity of 55.25%. Table 3 depicts that the CCR of the SVM method is 69.61% with a sensitivity of 99.20% and specificity of 2.05%. The CCR, sensitivity, and specificity of MLP model are 75.73%, 83.20%, and 56.68%, respectively, as shown in Table 4. As shown in Table 5, the CCR of the LR method is 74.48% with a sensitivity of 84.00% and specificity of 52.74%.

	Classified Class	
Actual Class	1 (normal)	2 (abnormal)
1 (normal)	923 (92.30%)	77 (7.70%)
2 (abnormal)	172 (39.27%)	266 (60.73%)
	Overall CCR : 82.68%	

Table 1. Classification Results Using RF Model

	Classified Class	
Actual Class	1 (normal)	2 (abnormal)
1 (normal)	529 (85.90%)	141 (14.10%)
2 (abnormal)	196 (44.75%)	242(55.25%)
	Overall CCR : 76.56%	

Table 2. Classification Results Using C4.5 Model

	Classified Class	
Actual Class	1 (normal)	2 (abnormal)
1 (normal)	992(99.20%)	8 (0.80%)
2 (abnormal)	429 (97.95%)	9(2.05%)
	Overall CCR : 69.61%	

Table 3. Classification Results Using SVM Model

	Classified Class	
Actual Class	1 (normal)	2 (abnormal)
1 (normal)	832(83.20%)	168 (16.80%)
2 (abnormal)	181 (41.32%)	257(56.68%)
	Overall CCR : 75.73%	

Table 4. Classification Results Using MLP Model

The summarized results of the five constructed models are shown in Table 6 and were used to evaluate their capability to predict postprandial blood glucose levels. From the data shown in the Table, we can conclude that the RF model has the best capability to predict postprandial blood glucose levels in terms of

the overall CCR. The SVM model has the highest sensitivity of 99.20% but has the lowest specificity of 2.05%. The RF model generated the highest specificity of 60.73% and the second-highest sensitivity of

	Classified Class	
Actual Class	1 (normal)	2 (abnormal)
1 (normal)	840(84.00%)	160 (16.00%)
2 (abnormal)	207 (47.26%)	231(52.74%)
	Overall CCR: 74.48%	

Table 5. Classification results using LR model.

92.30%. The RF model outperformed the five models in specific and general situations, indicating that it has better classification accuracy than the other five approaches. Therefore, the RF model is an effective alternative model for the prediction of postprandial blood glucose levels.

Algorithms	Overall CCR	Sensitivity {1-1}	Specificity {2-2}
RF	**82.68%**	**92.30%**	**60.73%**
C4.5	76.56%	85.90%	55.25%
MLP	75.73%	83.20%	56.68%
LR	74.48%	84.00%	52.74%
SVM	69.61%	99.20%	2.05%

Table 6. Classification Results of the Five Data Mining Models

CONCLUSION

Accurate and precise reasoning and prediction models greatly help physicians improve the diagnosis, prognosis, and treatment of diabetes. We used five data-mining techniques and designed a model for the prediction of postprandial blood glucose levels on the basis of the known risk factors of diabetes. The results showed that the RF approach exhibited the highest classification accuracy out of the five models. Its specificity and overall CCR were higher those of the C4.5, SVM, MLP, and LR models. Therefore, the RF model provides better classification accuracy than the other competing approaches and is an effective data-mining method for the prediction of postprandial blood glucose levels in a cohort study.

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ACKNOWLEDGMENT

This work is supported by the Chung Shan Medical University Hospital and LandSeed Hospital: CSMU-LSH-102-02.

International Journal of Management, Economics and Social Sciences
Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017)
2018, Vol. 7(S1), pp.142 – 154.
ISSN 2304 – 1366
http://www.ijmess.com

Benefits of Pre-Operative Concurrent Chemo-Radiotherapy among Elder Patients with Local Advanced Rectal Cancer

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The pre-operative chemo-radiotherapy (Pre-OP CCRT) in aged patients with stage III rectal cancer may be less effective. We collected data from 3365 patients (2004-2012) from Taiwan Cancer Registry. Metachronous colorectal cancer and multiple cancer patients were excluded. The patients were separated in three groups, operation first, Pre-OP CCRT first and treatment without operation. SAS 9.2 Student-t, ANOVA and Chi-Square tests were used for analysis. It was found that Group II had good survival curve than the group I (HR =0.26, p<0.0001). The group III had the worst survival benefit (HR=3.38, p<0.0001). Patients with age <75 Y/O had the same survival curve (p=0.0099). Patients age between75-80Y/O had worse survival time (HR=2.91, p<0.0001). The mortality rate increased dramatically in patients old than 85Y/O but the Pre-OP CCRT still provided survival benefit (HR=6.55, p<0.0001). Pre-operative CCRT improved survival in stage III rectal cancer. Even patients with 80~85 years old still had the benefit. In old patients without major comobility and good physical status, Pre-OP CCRT was still the best choice.

Keywords: Pre-operative concurrent chemo-radiotherapy (Pre-op CCRT), rectal cancer, local recurrence, survival time

The incidence of colorectal cancer (CRC) has increased in many countries in recent years. Due to the popularity of lower fiber and high-fat diet, the incidences of CRC elevated gradually. Colorectal cancer become a major cause of morbidity and mortality throughout the world and makes the treatment more important. CRC treatment is mainly done on tumor stage when it is diagnosed. The treatment guidelines for CRC, made by the National Comprehensive Cancer Network (NCCN) in the U.S., is used worldwide. Several countries use it as a standard. But in Taiwan, each hospital owns its modified guidelines according to operational ability rule.

Radical resection of colon cancer is simple in stages I-III, as radiotherapy or neoadjuvant chemotherapy is not necessary due to the movable anatomic structure of the colon. Rectal cancer treatment, however, is

Manuscript received May 23, 2017; revised June 15, 2017; accepted July 20, 2017.
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More difficult. Mendenhall *et al*. (1983) found a local advanced tumor (T3 or T4) cannot be controlled easily during operation and a high incidence of local recurrence was observed in the past.

Cedermark *et al*. (1997) presented preoperative concurrent chemoradiotherapy (Pre-OP CCRT) was then used and subsequently became a guideline for the past two decades. The procedure can achieve tumor shrinkage, increase success of the sphincter-saving operation, reduce local recurrences according to Habr-Gama *et al*. (1998), and increase disease-free survival by Jung *et al*. (2015), as well as decrease 5-year overall mortality, cancer-related mortality, and local recurrence rates by Camma *et al*. (2000).

Although the Pre-OP CCRT following with surgery becomes a general rule in rectal cancer treatment, colorectal surgeons in Taiwan may not follow it due to age, patient condition, and/or health insurance payment principle. In clinical practice, not all doctors obey the guideline, particularly when patients are over 75 years old. The factors included ECOG performance status of patients, comorbidity, age beyond life expectancy, and economic support of family.

There are no reports on whether elderly patients benefit by Pre-OP CCRT. Sanoff *et al*. (2012) found patients above 75 years old were excluded from most studies. So the group of old age patients need more attention in clinical practice. Most developed countries set the age of 65 as the beginning of old age. The definitions of old age continue to change as life expectancy in developed countries has risen to beyond 80 years old.

Therefore, it is unclear whether elderly patients receive standard treatment of rectal cancer and if doctors adhere to NCCN treatment guidelines for rectal cancer. In order to address these questions and monitor the treatment of local advanced rectal cancer, we used the database from Taiwan Cancer Registry. Our main objective was to determine whether old patients have the same benefit from Pre-OP CCRT as young patients. The result of this analysis can help doctors make good suggestions to old patients.

LITERATURE REVIEW

CRC is the most prevalent malignancy in Taiwan. Glimelius *et al*. (1995) had reported the incidence of rectal cancer is 35%-45% among all CRCs worldwide. The local failure rate plays an important role in the treatment

of rectal cancer. Scott *et al*. (1995) showed there were many techniques to improve the local failure rate including total mesorectal excision (TME), such as preoperative radiotherapy, CCRT, postoperative adjuvant chemotherapy, postoperative adjuvant CCRT, radiotherapy, etc.

Though many procedures are used, preoperative radiotherapy has been extensively investigated. Early in 1997, study by Cedermark *et al*. (1997) reported an overall 5-year survival rate of 58% in patients who underwent radiotherapy plus surgery and 48% in patients who underwent surgery alone. This is significant improvement of survival improvement in the war to rectal cancer. Since then, information from a number of controlled trials (Habr-Gama *et al*. 1998; Glimelius *et al*., 1995) indicates that the proportion of local recurrences is reduced to less than half when radiotherapy at moderately high doses is given preoperatively. A meta-analysis by Camma *et al*. (2000) showed in patients with resectable rectal cancer, preoperative radiotherapy significantly improved overall and cancer-specific survival compared with surgery alone. The magnitude of the benefit is relatively large and criteria are needed to identify patients most likely to benefit from adjuvant radiotherapy.

According to the NCCN guideline and related papers (e.g., Sebag-Montefiore *et al*. 2009, 2001, Tepper *et al*., 2002, Pucciarelli *et al*., 2000), Pre-OP CCRT is the standard of locally advanced rectal cancer treatment since 2003. Wagman *et al*. (1998) said that sphincter preservation could be achieved in 77% of patients who would otherwise require an abdominoperineal resection. Kachnic (2006) also concluded that preoperative chemoradiation therapy also allowed for the investigation of innovative agents (capecitabine, oxaliplatin, irinotecan, bevacizumab, and cetuximab) in combination with pelvic radiation. In Taiwan, the treatment guideline of all medical centers mainly follows the NCCN guideline, so all patients with rectal cancer are expected to receive the same treatment protocol.

Little data about the benefit of Pre-OP CCRT in elderly patients with rectal cancer. Sanoff and Goldberg (2007) reported the colorectal cancer treatment in older patients but limited the age of patients to 70 years old. A review of National Cancer Institute (NCI)-sponsored trials (Murthy *et al*., 2004) showed only “ 0.3%-0.5% of enrolled patients in these trials were older than 75. Old patients should be an important group in the colorectal cancer patients.

Gerontologists have recognized the diversity of old age by defining sub-groups. Zizza *et al.*(2009) used the sub-grouping as young-old (65 to 74), middle-old (75– 84), and oldest-old (85+). Forman *et al.* (1992) distinguishes the young old (60 to 69), the middle old (70 to 79), and the very old (80+). As there is no literature on the value of the NCCN guideline in elderly patients, we sought to design a study to determine this.

METHODOLOGY

This study used cancer registration data, provided by the Taiwan Cancer Registry, from rectal cancer patients diagnosed with clinical or pathological stage III cancer with no distal metastasis from 2004 to 2012. Patients selected were 18 years of age and above, and were placed into three groups: (1) Patients who underwent direct surgery and had postoperative pathological stage (pStage) III, (2) Patients with clinical stage (cStage) III who underwent tumor resection after Pre-OP CCRT, and (3) Patients with cStage III who underwent chemotherapy, radiotherapy, CCRT, or supportive treatment but did not undergo any tumor resection surgery. Subgroups were made according to the post treatment pathologic stage (ypStage) and following treatments after tumor resection.

In Taiwan, the physical status of people younger than 75 years old seem to be gathered in the same sub-grouping, So each sub-group was further divided into four age groups, namely, 70 years old and below, 70-74 years old, 75-80 years old and 80 years old and above. We analyzed the choice of treatment regimen in each age group and whether there were significant differences in the compliance rates.

What condition means treatment adhere to the guidelines? Certain restrictions were needed for the time course in the experiment, and patients that were unable to complete the treatment regimen within a fixed time period were excluded from this study. For Group 1, the time of diagnosis to day of surgery must be within 60 days, and the start date of postoperative radiotherapy and chemotherapy must be within 90 days from the day of surgery. For Group 2, the time of diagnosis to start date of radiotherapy must be within 60 days and surgery must be carried out within 60 days from completion of radiotherapy. The start date of postoperative chemotherapy must be within 90 days from the day of surgery. For Group 3, patients only

underwent radiotherapy, chemotherapy, CCRT, or were not given treatment at all. Patients also did not undergo tumor resection surgery after diagnosis.

Data processing and statistical analysis was conducted using SAS 9.2 statistical software. Descriptive and correlation statistics analyses were used in the study. Independent and dependent variables were evaluated to find the demographic characteristics of rectal cancer patients (age, gender), treatment course characteristics, and post-treatment status. Survival status and relevant prognosis of rectal cancer patients were also calculated in different treatment regimens (such as with or without radiotherapy), or different age groups after undergoing radiotherapy. The Cox Proportional Hazard Model was used to estimate Hazard Ratios (HR) and 95% confidence intervals.

RESULTS

From 2004 to 2012, the total number of patients in the Taiwan Cancer Registry that fulfilled the inclusion criteria of this study were 3,365. There were 2,040 males and 1,325 females. The average age was 57.1 years. There were 2,004 patients in Group 1, 1,044 patients in Group 2, and 317 patients in Group 3. According to the regulations by the Taiwan Ministry of Health and Welfare, data from groups with fewer than five people were not shown. Therefore, some fields are empty in Table I (see Appendix-I).

Patient demographics and characteristics are listed in Table 1. In Group 1, the most common postoperative adjuvant treatment was CCRT (1,444 patients; 72%), with follow-up as the second treatment plan used (359 patients; 17.9%), and radiotherapy as the least often (19 patients; 0.9%).

The postoperative cancer stage in Group 2 ranged from ypStage 0 to ypStage III. The same preoperative and postoperative stage was observed in 438 patients (42.0%) and the rest had tumor downstaging. The median follow-up times were similar (10.5-12.6 months) among all groups and subgroups except Group 3 (6.6 months) and the F/U subgroup in Group 1 (7.8 months).

The results of the univariate and multivariate Cox regression analyses for cancer-related mortality are listed in Table 2. Univariate analysis using Cox proportional hazard modeling showed the Group 2 had a significant better effect in treatment group (HR 0.26, $^{**}p<0.001$). The Group 3 patients had high cancer-related mortality than the patients in Group 1 (HR 3.38, $^{**}p<0.001$). The survival curve is shown in Figure 1. In Age group (Figure 2), the patients aged 70-75 seemed to have trend about worse survival benefit than the

patients aged below age 70 , but there is no statistical difference in multivariate Cox regression model (HR 1.03, p=0.04). And the patients age 75-80 and age >= 80 had high mortality rate than patient aged below 70. The same results were also noted in multivariate Cox regression model. The Group 2 showed best survival benefit despite patient in all age group (Figure 2, 3)

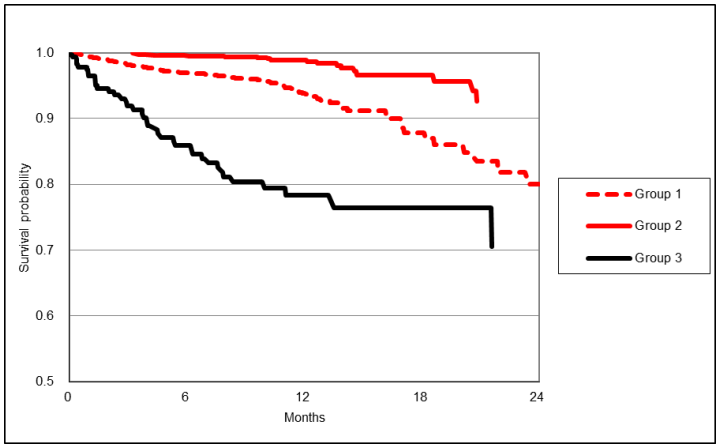

Figure 1. Survival Probability by Treatment Group

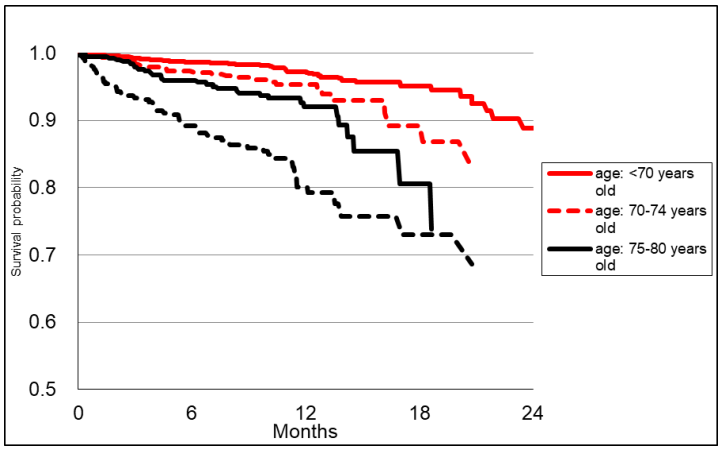

Figure 2. Survival Probability by Age Group

DISCUSSION

Preoperative CCRT has been included in the rectal cancer treatment guidelines of the world and Taiwan for more than 10 years. Hines *et al.* (2015) has reported the guideline-adherent treatment was received by

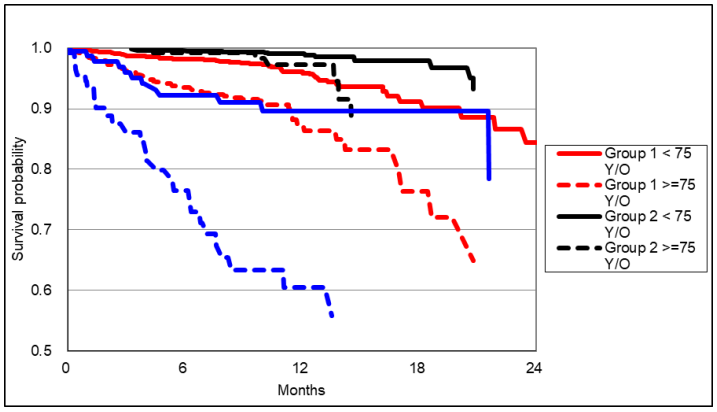

Figure 3. Survival Probability by 75 Y/O Boundary

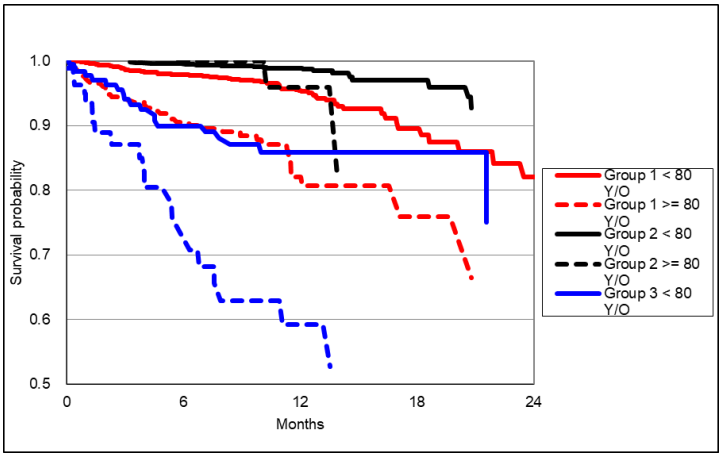

Figure 4. Survival Probability by 80 Y/O Boundary

	Univariate Cox regression			Multivariate Cox regression		
	HR	95% C.I. of HR	P value	HR	95% C.I. of HR	P value
Treatment group						
Group 2 vs. Group 1	0.26	[0.16,0.42]	<0.001	0.32	[0.20,0.52]	<0.0001
Group 3 vs. Group 1	3.38	[2.36,4.85]	<0.001	2.70	[1.67,3.90]	<0.0001
Age group						
Aged 70-75 vs. aged <70	1.83	[1.16,2.90]	0.0099	1.03	[1.03,2.59]	0.0375
Aged 75-80 vs. aged <70	2.91	[1.90,4.46]	<0.001	2.66	[1.73,4.07]	<0.0001
Aged >=80 vs. aged <70	6.55	[4.61,9.30]	<0.001	4.44	[3.09,6.36]	<0.0001

Table 2. Univariate and Multivariate Cox Regression for Cancer Related Mortality (N=3365)

82.7% of patients. However, according to the data collected in this study, there were more patients that did not receive Pre-OP CCRT (groups 1 and 3; 69%) compared to those that did receive Pre-OP CCRT (Group

2; 31%), suggesting that the percentage of adherence in Taiwan is lower. Thus, there is a gap in current awareness that most physicians obey the treatment guideline as far as possible. Because there appears to be a discrepancy between real-world practice and treatment guidelines in the treatment of rectal cancer, the reasons behind this discrepancy should be investigated. Patients may refuse the suggestion in treatment plan due to lack of medical knowledge and poor physical status (ECOG). In Taiwan, the family support system plays a major role in the treatment selection of patients.

With regard to Group 1, a majority of patients (72.1%) underwent postoperative adjuvant CCRT. This was followed by adjuvant chemotherapy (CT) (9.1%). The number of patients who underwent adjuvant radiotherapy (RT) was very low (0.9%). However, about 17.9% of patients did not undergo any CT or RT following surgery. This group of patients was relatively older in age (average 70.3 years) compared to patients who received postoperative treatment, whereas the average age of patients who underwent adjuvant CCRT was the lowest (add average). Thus, the physician may adjust the postoperative adjuvant treatment based on age.

The number of patients in Group 2 was lower than expected. As mentioned previously, this group of patients accounted for 31% of the total patients in this study, and the subgroup distribution was extremely uneven, with some subgroups housing less than ten patients. The reason for this could be that the preoperative clinical stage of all rectal cancer patients was determined using computed tomography imaging. However, a pelvic computed tomography scan could detect regional lymph node enlargement, and few patients fulfilled the criteria for stage III. This is due to the limitations in imaging precision and AJCC guideline (Edge *et al.*, 2010) also states that lower stages cannot be determined as the clinical stage of patients. The number of patients may not match the physician's expectation by stage, thus the number patients with clinical stage III cancer may be underestimated. To improve classifying clinical stage, magnetic resonance imaging (MRI) was advised by some physicians (Adeyemo and Hutchinson, 2009, Nerad *et al.*, 2017). Positron Emission Tomography (PET)-CT is also a more useful and powerful tool to accurately determine staging of tumors compared to traditional CT (Buijsen *et al.*, 2011).

The number of patients in Group 2 who underwent Pre-OP CCRT, did not have any tumor cells in postoperative specimens, and achieved complete tumor remission (ypStage 0) was very low (7 patients; <1%). This is lower than the 17%– 25% reported in the literature (Maas *et al.*, 2010, Yoon *et al.*, 2015). The difference may be due to the reason that this study used a Taiwanese population or the earlier inclusion date of patients in the Taiwan Cancer Registry. A report by Lee *et al.* (2008) also had a low complete response rate (5.3%) in Korea, but this is still higher than what we report. More data is needed to determine the reason for this difference.

There were 599 patients (57%) in Group 2 that were downstaged to ypStage I and ypStage II. Yang *et al.* (2005) reported the TNM stage after Pre-OP CCRT, where 60% of patients were downstaged, and similarly, Lee *et al.* (2008) reported a downstaging rate of 52.6%. Our results are consistent with these previous reports, suggesting that about half of rectal cancer patients may have an advantage in receiving the procedure.

The majority of patients in groups 1 and 2 were aged 70 and below. There were no large differences in the number of patients aged 70-75, 75-80, and older than 80 years. However, in Group 3, the number of patients with 80 years of age or older were the largest among the three treatment groups (n = 87; 27.5%) while the number of patients 70 years old and younger were the lowest (n = 128; 49.8%), which was lower than half the number of patients. A similar trend for adjuvant treatment can be found in Group 1. The average age (70.3 years) in the follow-up (F/U) group is older than the other three subgroups (Table 1). Age appeared to be a major factor when selecting treatment regimen. According to the Cox regression analysis and the survival curves, significant differences in cancer-related mortality were seen when the data was split by age, with patients 80 years and older showing greater mortality rates and patients 75 years and older showed lower patterns of survival compared to their younger counterparts. Zizza *et al.* (2009) and Forman *et al.* (1992) had reported the different sub-groupings for "old", we can distinguishes the young old (65 to 74), the middle old (75 to 79), and the very old (80+) in Taiwan CRC patients. In our study, for patients aged 80 years and older, survival rates could decrease drastically (Figure 4). However, if patients aged 75 years and older underwent appropriate surgery, their survival rates could approach that of patients aged below 75 who did not undergo surgery (Figure 3).

Group 2 had the best treatment outcome, with Group 1 showing better prognosis compared to Group 3. There were no significant differences for patients under 75 years of age. Differences start to appear in the age group of 75-80 years, and mortality probability starts to drastically increase at age 85 years and older. Preliminary results from a follow-up period of 24 months showed that the Pre-OP CCRT group had the best survival rate regardless of age. This result may be useful for modifying current treatment guidelines (Jung *et al.*, 2015).

CONCLUSION

Factors associated with guideline adherence included age, comorbidity index, insurance status, and level of hospital. Pre-OP CCRT is currently used as a standard treatment for stage III rectal cancer. It was not known if elderly patients benefited from the procedure; now, the results of this study suggest that these patients (even patients older than 80 years old) can still follow the guideline. Pre-OP CCRT following with operation results is the best outcome of this study and the literature review. The guideline is suitable in Taiwan also. Physicians could suggest patients receive the treatment procedure regardless of the age.

LIMITATIONS AND FUTURE DIRECTIONS

This study did not use the death registry; therefore, we were unable to accurately obtain the time of death. In addition, the cancer registry staff registered patients' data within one year of diagnosis and uploaded data according to year, so 3-year and 5-year survival data are not available. We are awaiting access to health insurance data to tabulate the Charlson Comorbidity Index and treatment choice according to existing subgroups, in order to determine the actual survival rate and disease progression rate.

Some stage III patients did not undergo resection surgery, and the reasons for this could not be obtained using the cancer registry. It is possible that these patients may have comorbidities and were unable to undergo surgery, that they have high surgery risk, or that the patient and their family members refuse radical surgery. We found that patients in Group 3 had very low survival rates and almost all patients died within two years. To determine whether comorbidity factors influenced our results, further access to health insurance data is needed.

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ACKNOWLEDGEMENT

This research is sponsored by the Chung Shan Medical University Hospital, under Grant no CSH-2013-A-040.

Appendix-I

Treatment		Group I				Group II								Group III
Tatal Number (%)		2004 (59.56%)				1044 (31%)								317 (9.4%)
Stage		pStage III				ypStage 0		ypStage I		ypStage II		ypStage III		cStage III
		F/U	CCRT	RT	CT	F/U	CT	F/U	CT	F/U	CT	F/U	CT	--
Number (% in each group)		359 (17.9%)	1444 (72%)	19 (0.9%)	182 (9.1%)	5 (0.48%)	2 (0.2%)	117 (11.2%)	129 (12.4%)	149 (14.3%)	204 (19.5%)	119 (11.4%)	319 (30.6%)	317
Median F/U time (Month)		7.8	11.6	11.0	12.6	10.5	--	15.7	12.4	14.3	12.7	14.3	12.4	6.6
Time from CCRT to surgery (Day)		--	--	--	--	45.8	--	43.7	48.8	43.9	45.0	45.0	43.2	--
No.	<70 Y/O	1196 (69.7%)				785 (75.2%)								128 (49.8%)
	70-75 Y/O	279 (13.9%)				127 (12.2%)								37 (11.7%)
	75-80 Y/O	268 (13.4%)				94 (9.0%)								35 (11.0%)
	>=80 Y/O	261 (13.0%)				38 (3.6%)								87 (27.5%)
Age Average		70.3	64.3	67.3	63.3	51.7	--	62.2	60.2	60.8	59.9	60.0	59.1	68.8
Gender	M	1154 (57.6%)				692 (66.3%)								194 (61.2%)
	F	850 (42.4%)				352 (33.7%)								12 (38.8%)

F/U: follow-up, CCRT: concurrent chemohradiotherapy, RT: radiotherapy, CT: chemohterapy
Group II: all were cStage II

Table 1. Demographic Characteristics of All Patients (N=3365)